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Articles report surveys and research studies as well as describe systems in educational technology. Areas treated include the following: multihandicapped blind and deaf blind children in California, by B. Lowenfeld; modern trends in mobility, by J.A. Leonard; factors in the definition of deafness as they relate to incidence and prevalence, by J. D. Schein; trachoma, by G.H. Werner and others; and learning eye fixation without visual feedback, by B.L. Toonen and J.P. Wilson. Also considered are the effect of signal strength on reaction times to auditory signals in noise, by D. Liddle; a closed circuit television system for the visually handicapped, by S.M. Genensky and others; devices for communication through tactile perception, by J.C. Bliss and H.D. Crane; and altered levels of consciousness in blind retarded children, by A.C. Stone. Current research notes are provided along with information on autobraille, the automated braille system. (JD)

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# MULTIHANDICAPPED BLIND AND DEAF-BLIND CHILDREN IN CALIFORNIA*

**Berthold Lowenfeld**

*The Study of Multihandicapped Blind Children in California was carried out under a contract with the California State Department of Education. There are many people, teachers, administrators of public and private schools, directors of private agencies, parents and parent-group representatives, those who work with blind preschool children, medical experts, and alumni representatives of the California School for the Blind, who gave most valuable assistance to the study either by completing the questionnaires or by giving me the benefit of their advice. To all of them, I owe a debt of gratitude and hope that the results of this Study will justify the confidence expressed by their cooperation.*

*I want to express my special thanks to Mr. S. W. Patterson, Assistant Chief, Division of Special Schools and Services, Department of Education, State of California, for his constructive support of the Study.*

## 1. STATISTICS

### Questionnaires

Two questionnaires were developed in order to determine the characteristics (numbers, nature, extent, and location) of the multihandicapped blind population under 21 years of age in California. Questionnaire A (see Appendix) was designed to collect data about multihandicapped blind children in school, and Questionnaire B (see Appendix), about those not in school.

The questionnaires were pretested with teachers and their supervisor at the California School for the Blind. The replies, independently filled out by the teachers and the supervisor for 72 children, showed a high degree of sameness or similarity which indicated that the questionnaires were valid instruments for the purposes pursued by the study.

### Distribution of Questionnaires

In order to determine which programs for the educable and trainable mentally retarded and for the orthopedically handicapped had any blind children, 560 return postal cards were

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**A report submitted to the California State Department of Education, Division of Special Schools and Services.*

mailed to all such programs. Reply cards were received from 476 of these, or a response of 85 percent.

Questionnaires A and B were subsequently mailed to 747 addresses. These comprised all sources from which replies concerning multihandicapped blind children might be expected, such as:

County superintendents of instruction
Special education personnel in county and local schools. If such personnel was not listed, the material was sent to the Principal
Programs for visually handicapped children
California School for the Blind (CSB)
Programs for educable and trainable mentally retarded and orthopedically handicapped children whose reply cards indicated that they had multihandicapped blind children
State Department of Mental Hygiene
State Hospitals for Mentally Retarded
State Schools for the Deaf (CSD)
State Diagnostic Centers for Neurologically Handicapped Children
County and city public health nurses
Development Centers for Handicapped Minors (DCHM)
State preschool workers in Los Angeles
Variety Club Blind Babies Foundation's preschool workers in San Francisco
Private Agencies such as:
  John Tracy Clinic, Los Angeles
  Blind Children's Center, Los Angeles
  Braille Institute of America, Los Angeles
  Foundation for Junior Blind, Los Angeles
  Exceptional Children's Foundation, Los Angeles
  San Francisco Lighthouse for the Blind
  San Francisco Hearing and Speech Center
  Recreation Center for the Handicapped, San Francisco
  Clearwater Ranch, Santa Rosa
  Plumfield School, Santa Rosa
  Lucinda Weeks School, San Francisco
  Easter Seal Society, Sacramento
  American Foundation for the Blind, New York City
  Rubella Parents Association, Pico Rivera

and a number of ophthalmologists, psychiatrists, and pediatricians who were known to have professional contacts with blind children.

Thus, inquiries were sent to 1,307 programs concerned with handicapped children, including the postal cards already described. Replies were received from 613 sources, or 47 percent of the total mailing. In view of the fact that inquiries were sent to programs for handicapped children of all kinds, of which many certainly did not have any blind children, this return must be considered highly satisfactory. A checkup revealed that all known programs for blind children had replied.

Numerous follow-up efforts were made by conferences and telephone calls to support the case-finding efforts. A deep and active interest in the study was shown by all concerned. It is a conservative estimate that 80 to 90 percent of the multihandicapped blind children's population is included in the study.

## Statistical Analysis of the Questionnaires

The tables presented in this report include all data received by March 29, 1968.

Table 1 gives the over-all classification and numbers of multihandicapped blind children in California. The first four lines report the numbers of *(1)* multihandicapped blind children in school, *(2)* in state hospital schools, *(3)* not in school, and *(4)* of preschool age. The next four lines report the same for deaf-blind children. The latter are not included in the first four lines. As can be seen from Table 1, there are 1,180 multihandicapped blind children in California of whom 940 are blind children with multiple handicaps (excluding deafness) and 240 are deaf-blind children. There are no statistics available on the number of multihandicapped blind children during past years. A report of the National Study Committee on Education of Deaf-Blind Children (March, 1956) gives the results of a national survey for 1954/1955 which "showed a total 245 deaf-blind children as of March 1, 1956" in the United States. At present there is about the same number (240) in California alone. In addition, there are 1,217 visually handicapped patients under 21 years of age in state hospitals not receiving any special education (100 of the 1,317 children in state hospital schools are reported on lines 2 and 6).

### *Multihandicapped Blind Children in School*

Tables 2A, B, and C present data on the 537 multihandicapped blind children in school. Table 2A gives their year of birth, grade placement, visual acuity, and cause of blindness.

It can be seen that the year 1953 stands out as the one in which the largest number of multihandicapped children were born. From 1954 on, the numbers decreased which is undoubtedly due to the fact that after 1954 control of retrolental fibroplasia became increasingly effective.

The grade placement of these children does not show a corresponding peak in the seventh or eighth grade. This is understandable because multihandicapped blind children do not progress in the normal way from grade to grade. Therefore, their grade placement does not follow the year of birth pattern but is more evenly distributed. Of the 537 children, 239 (45 percent) are ungraded.

The visual acuity distribution shows that at least 187 (35 percent) of the children have a severe visual loss, while 303 (56 percent) of them are listed as falling under the legal definition of blindness or having better vision than that. Visual acuity was not reported for 47 children (9 percent).

The largest single cause of blindness in this group was retrolental fibroplasia (168 children, or 31 percent); next are cataracts (57, or 11 percent); and optic atrophy (42, or 8 percent). For 63 children (12 percent), the cause of blindness was not reported.

Table 2B is a summary of the handicaps listed for each child and also gives data on the recommendations for the future placement of the children. Of the 537 children, 350 (65 percent) are mentally retarded, about one half of whom fall into the educable range. The next most frequent handicap is "emotional" with 214 children (40 percent) being thus listed. Speech handicaps are listed for 143 children (27 percent). The other handicaps occur for smaller numbers of children though it should be noted that 76 (14 percent) show varying degrees of cerebral palsy and 48 (9 percent) have orthopedic handicaps.

The severity of the handicaps indicates that 30.5 percent of the handicaps are mild, 24.9 moderate, 12.7 severe, with 31.9 percent "degree not reported."

The numbers of handicaps in addition to blindness range from 244 children with only one additional handicap to one child with seven additional handicaps. The average number of handicaps per child (including blindness) was found to be 3.0. This is almost the same number reported by James M. Wolf in *The Blind Child with Concomitant Disabilities* in which a total of 453 mentally retarded blind children in residential schools were included. Wolf found an average number of 3.18 concomitant handicapping conditions per child.

No recommendations for future placement were given for 132 children, and for only 35 (7 percent) did the teachers indicate that they should not remain in their present placement. In considering this small percentage, one must keep in mind that the only practical alternatives for the placement of children who "should not remain," are either sending them home and leaving them without any educational provision or having the parents commit them to a state hospital.

Table 2C gives the county distribution of 433 blind children; 104 who are placed at the California School for the Blind were not included. Of the 433 children, 249 (58 percent) reside in Southern California and 184 (42 percent) in Northern California.

### *Multihandicapped Blind Children in State Hospital Schools*

Tables 3A and 3B give the relevant statistics for 82 multihandicapped blind children in State Hospital Schools. According to Table 3A, 1953 and 1954 are peak years of birth for this group also.

Since state hospital schools do not function by a grade system, all children are ungraded.

This group of children follows, so far as the severity of the visual handicap is concerned, the same pattern as reported in Table 2A. At least 26 (32 percent) of the children are severely visually handicapped, while 46 (56 percent) are listed as "blind." For 10 children (12 percent) no visual acuity was reported.

Among the causes of blindness, retrolental fibroplasia ranks first with 29 (35 percent) and cataracts second with 7 (9 percent), also similar to the group reported in Table 2A. Cause of blindness was not reported for 26 children (32 percent).

As Table 3B shows, 82 children are mentally retarded, most of them (64 or 78 percent) in the trainable category. Among others, communication, speech, and emotional handicaps are more frequently listed. This group of 82 children has almost 50 percent of its handicapping conditions in the moderate (trainable) classification. This raises the question of why they were committed to state hospitals. Some of them most likely have other handicaps, such as emotional or psychotic ones, which explain their placement; others may be where they are because no other facilities were available. Also, some of them may have been admitted at a young age and remained there though their condition improved.

The average number of handicaps per child, including blindness, is 3.7, almost one more handicap than reported for children attending regular schools (Table 2B).

### *Multihandicapped Blind Children (School Age) Not Attending School*

Tables 4A, 4B, and 4C deal with 189 multihandicapped blind children of school age who are not attending school.

Table 4A shows that the peak years of birth for this group were 1952, 1953, and 1954, again the last years of the retrolental fibroplasia epidemic.

Of these children, 115 (61 percent) live at home. 60 (32 percent) have left school, most likely because they were not making any progress, and are also at home, and for 14 children (7 percent) placement was not reported.

This group is largely a low visual acuity group with 108 children (57 percent) reported as being either totally blind or having a severe visual loss. This is far more than the 35 percent reported for multihandicapped blind children in school (Table 2A).

The outstanding cause of blindness is again retrolental fibroplasia, reported for 48 (25 percent) of the children. Next is optic atrophy, congenital blindness, glaucoma, and cataracts. Cause of blindness was not reported for 51 children

(27 percent), which is more than twice as large a percentage as reported for children in school.

Table 4B presents information on the handicaps of the group. Mental retardation is reported for 130 (69 percent) of the 189 children. Emotional handicaps are next with 84 children (44 percent) being affected. Besides hearing and the concomitant communication and speech defects, cerebral palsy is reported for 36 (19 percent) of the children and orthopedic handicaps for 19 (10 percent).

The average number of handicaps per child is 3.0. This is by comparison with other groups a small number. However, it must be kept in mind that there are multihandicapped blind children not in school and, therefore, the identification of handicaps present in many children, as well as the degree of their severity, has not been reported as reliably and frequently as for the other groups. The parents or short-term visits by a professional representative are in most cases the only source of information available.

Table 4C shows the county distribution of these children: 87 (56 percent) live in Southern California and 69 (44 percent) in Northern California. Residence has not been reported for 33 of them.

### *Multihandicapped Blind Children of Preschool Age*

Table 5A shows that most of the 132 multihandicapped blind children of preschool age were born in the years 1962 to 1965. It is most likely that some of the children born in 1967, and certainly those born in 1968, have not yet been reported, since it is difficult or impossible to determine additional handicaps and their severity in children of such a young age.

Practically all of these young children live with their families, since most of those listed as attending the Blind Children's Center in Los Angeles, preschool groups, an orthopedic school, Development Centers for Handicapped Minors, and those whose placement whose placement was not reported, are not in residence there. The four children listed as being in state hospitals were reported by agencies that either have served them in the past or are still serving them.

The majority of the children whose visual acuity has been reported are severely visually handicapped (64 out of 84). Fourteen are listed as having partial vision.

Rubella is the predominant cause of blindness (79, or 60 percent), followed by retrolental fibroplasia, cataracts and optic atrophy. The 79 rubella children are a minimum because there are most likely additional ones listed under cataracts and cause "not reported."

Table 5B shows that 102 of the 132 children (77 percent) are mentally retarded with only 12 of them in the educable category. Communication and speech handicaps were reported for 65 (49 percent) and 49 (37 percent) children respectively. Fifty-three (40 percent) had emotional difficulties, most of them in the moderate and severe ranges. Only 11.7 percent of the handicapping conditions reported fall into the "mild" classification, compared with 30.5 percent for multihandicapped blind children in school.

The number of handicaps reported for each child in addition to his blindness ranges from 35 children having only one to one child having seven handicaps.

The average number of handicaps per child (including blindness) was 3.7, which is 0.7 more than reported for multihandicapped blind children in school. The difference may be even greater because the reporting of handicaps for children in school is more likely to be complete than that for preschool blind children. Thus, it is certain that the present-day group of multihandicapped blind children of preschool age is more severely handicapped and will, when they become of school age, be a more severely handicapped group of school children than those presently enrolled in schools.

Table 5C shows that by county distribution 82 (63 percent) of the 130 children for whom residence was reported live in Southern California and 48 (37 percent) in Northern California.

### *Deaf-Blind Children in School*

Tables 6A, 6B, and 6C give the personal data on 58 deaf-blind children who are placed in educational provisions.

Data of Table 6A show the distribution of their years of birth. There are two peaks of three-year periods: 1952 to 1954 when 18 children were born and 1958 to 1960 when 24 children were born. During the earlier three-year period, six of the 18 children had their handicaps caused by retrolental fibroplasia. The control of retrolental fibroplasia began to take effect only after 1954. In the more recent three-year period, between 1958 and 1960, twelve of the 24 children had their cause of blindness indicated as either cataracts or rubella cataracts. It can be surmised that at least some of the cataracts reported were also rubella cataracts and that the same is true for some of the five children listed under cause "not reported." It is known that around 1959 a rubella epidemic occurred in the western part of the United States.

Fourteen deaf-blind children receive their education in the Deaf-Blind Department of the California School for the Blind, and two others are placed in regular classes for blind children at that school. One child, listed as attending a provision for the deaf, attends the California School for the Deaf in Berkeley (her visual handicap is listed as moderate), and another attends a Development Center for Handicapped Minors. All other children for whom a placement was reported attend local school provisions: one in a kindergarten, 22 in regular grades, nine ungraded, and six in classes for the deaf and hard-of-hearing. Placement was not reported for two deaf-blind children.

At least 38 of the 58 children have severe visual handicaps and only two were registered as partially seeing. Visual acuity was not reported for six.

Thirty-nine of the 58 children have severe or moderate hearing losses while the degree of hearing loss was not reported for the remaining 19 children. It stands to reason that those for whom the degree was not reported are likely to be either in the severe or moderate range, since a mild hearing loss can be rather easily determined as such.

Under Cause of Blindness, cataracts were reported for eleven, rubella for eight, retrolental fibroplasia for seven, congenital for six, and optic atrophy also for six. For five children the cause was not reported.

Table 6B shows that 32 children were reported as mentally retarded, only five of whom as uneducable. Only 24 and 25 had communication and speech disorders respectively; many, if not most of them, have both together. Since there are 58 deaf-blind children in school, it must be assumed that a considerable number of them had acquired speech before they became deaf or that their moderate hearing loss did not interfere with the acquisition of speech and implicitly communication. Eleven of the children also had emotional handicaps.

The distribution of handicaps in addition to blindness shows that 16 children were deaf-blind and had no other handicap reported, while the remaining 42 had two up to seven handicaps in addition to their blindness.

The average number of handicaps per child, including blindness and deafness, is 2.8. This shows that deaf-blind children in school have on the average fewer handicaps in addition to their deaf-blindness than any other group.

The recommendations for future placement of these children indicate that only three of them should not remain in their present placement, 38 should remain, and for the remaining 17 no recommendation was made.

Of the 42 children for whom counties of residence were reported in Table 6C, twenty-six (62 percent) reside in Southern California and 16 (38 percent) in Northern California. County of residence was not reported for 16 children at the California School for the Blind.

### *Deaf-Blind Children in State Hospital Schools*

The numbers in this group of 18 deaf-blind children, reported in Tables 7A and 7B, are too small to allow any statistical conclusions. All children in State Hospital Schools are in ungraded classes. Their hearing loss is either moderate or severe, and their causes of blindness are cataracts, rubella, retrolental fibroplasia, and pigmentary degeneration which was given for two children who are apparently twins since they have the same birthdate.

The distribution of handicaps in Table 7B shows that 16 of the 18 children have communication and speech difficulties. The average number of handicaps per pupil is 4.2, higher than that given for deaf-blind children in school.

### *Deaf-Blind Children (School Age) Not in School*

What was said about statistical conclusions concerning the previously described group also holds true for the 35 deaf-blind children of school age who are not in school, as reported in Tables 8A, 8B, and 8C. However, certain facts can be discerned.

No children were reported as having mild or moderate hearing losses; hearing loss was indicated as being severe for 22 and was not reported for 13 children. The causes of blindness are cataracts, rubella, brain damage, microcephalos, and retrolental fibroplasia.

Twenty-one of the 35 children are mentally retarded, ten of whom uneducable. Communication and speech difficulties are present in 18 each. A rather large number of these children have orthopedic problems (15 out of 35) with only one being registered as "mild."

The number of handicaps per child shows that 12 of the 35 children have no other handicap except their deaf-blindness. Nine of these children were reported by the American Foundation for the Blind in New York from their registry of deaf-blind children, which did not include information about additional handicaps. This makes the data on handicaps incomplete.

The average number of handicaps per child is 4.5 which is the highest average recorded for any of the eight groups in the study. Due to the above-explained lack of information for nine children, the average would be even higher if complete information had been available for these children.

County residence (Table 8C) was not reported for five children. Of the remaining 30, twelve reside in Southern California and 18 in Northern California. It should not surprise anyone that with such small numbers the population majority of Southern California is not necessarily reflected. It is interesting to note that the three deaf-blind children in Placer County (Northern California) are siblings and have the same cause of blindness, microcephalos.

### *Deaf-Blind Children of Preschool Age*

An unexpected large number of deaf-blind children of preschool age was reported--129. It should be remembered that in the past years--the prerubella years--only about 20 to 25 deaf-blind children of preschool and school age were identified in California.

The "year of birth" data in Table 9A show that during the three-year period from 1961 to 1963, thirty-four deaf-blind children were born/ during the three-year period of 1964 to 1966, ninety-three deaf-blind children were born. The reports given for 1966 and 1967 almost certainly do not give actual numbers because deafness is not always recognized at an early age.

The placement of these children shows that while all of them live with their families, 19 receive some attention at the John Tracy Clinic in Los Angeles (minimal as it must be since this facility serves deaf children only), 12 attend a special group of preschool deaf-blind children at the San Francisco Hearing and Speech Center, seven a similar group under the auspices of San Francisco State College, and five children attend other programs for preschool children.

Visual acuity was not reported for 65, one half of the children. Of the other one half, 47 children were severely visually handicapped, and 17 had some sight, seven of whom were listed as partially seeing. Not surprisingly, for reasons already pointed out, the degree of hearing loss was not reported for 81 of these young children, almost two thirds. Of the remaining ones, 45 had a severe hearing loss and only three a moderate loss. Thus, it appears that most of the children for whom visual acuity and degree of hearing loss were reported are severely visually and auditory handicapped.

Cause of blindness data tell the real story. Ninety-two (71 percent) are rubella children, a number that must be augmented by some of the seven who were reported as cataract cases and of the seven who were listed as cause "not reported." The other causes occurred in only small numbers.

Table 9B enumerates the additional handicaps of these children. Ninety-four (73 percent) of them are listed as having various degrees of mental retardation. This is a very high percentage but it must be recognized that any deaf-blind preschool child who has not been observed and adequately assisted over a considerable period of time does give the impression of being mentally retarded although he may have a much better potential. The comparatively small numbers of communication and speech handicaps listed are due to the fact that for many children of that young age, communication or speech development cannot be expected, even if they had normal hearing. Since rubella is the prevailing cause of handicaps for this group of children, the high incidence of heart defects (32, or 25 percent) must be expected. Cardiac conditions are a part of the rubella syndrome triad--cataracts, hearing loss, and heart abnormalities.

The severity of the handicaps is indicated by the fact that 32 percent are listed as severe, 10 percent as moderate, and only 4 percent as mild. For 55 percent the degree of the handicap was not reported. The number of handicaps per child shows that only 17 of the 129 children have no other handicap listed besides their deaf-blindness. All the others have from one to six additional handicaps.

The average number of handicaps for this group is 4.4, almost equaling that of the most disadvantaged group of other deaf-blind children, those not in school.

The distribution by county residence shows that 69 of the 129 children (54 percent) reside in Southern California while the remaining 60 (46 percent) live in Northern California.

### *Severity of Handicaps*

Table 10 presents, for seven groups of multihandicapped blind and deaf-blind children, a comparison of the severity of handicaps, reported either as mild (educable), moderate (trainable), severe (uneducable), and degree not reported. Table 11 gives the average number of handicaps per child for these seven groups. The eighth group, that of deaf-blind children in State Hospital Schools, numbered only 18 and, therefore, the percentages were too small to be meaningful.

A comparison of the percentages reported as "mild" shows that multihandicapped blind children in school have the highest percentage in this degree of severity, while deaf-blind children not in school and deaf-blind children of preschool age show the lowest percentage of mild handicaps. Conversely, multihandicapped blind children in school show the lowest percentage of severe handicaps while deaf-blind children not in school and of preschool age, with deaf-blind children in school, show the highest percentages of severe handicaps. The largest percentages of handicaps "not reported" are listed for deaf-blind children of preschool age (54.5 percent), for multihandicapped blind children not in school (53.3 percent), and for multihandicapped blind children of preschool age (43.9 percent). This stands to reason because children not in school and of preschool age are less likely to be sufficiently well observed by trained personnel to have the degree of severity of their handicaps determined. On the other hand, this underlines the need for diagnostic facilities for these children. Deaf-blind children not in school (27.4 percent degree of severity not reported) appear to be an exception. The fact that 58.9 percent of them had handicaps of a severe nature that was most likely easy to recognize, explains the low percentage of degree "not reported" for this group.

### *Average Number of Handicaps Per Child*

Table 11 lists the average number of handicaps for the seven groups of children. As already observed, the largest average number of handicaps per child was found for deaf-blind children not in school (4.5) and for deaf-blind children of preschool age (4.4). The smallest number (3.0) was shown for multihandicapped blind children in school and for multihandicapped blind children not in school. Thus, multihandicapped blind children of school age, whether they are in school or not in school, have an equal average number of handicaps. However, the distribution of the degree of severity of handicaps is much more favorable for those in school than for those not in school.

### *Frequency of Handicaps for 940 Multihandicapped Blind Children*

Table 12 gives the frequency of handicaps for the four groups of multihandicapped children, not including the deaf-blind. Mental handicaps occur in 664 children (70.6 percent) and they are the most frequently occurring handicap in each of the four groups. Emotional handicaps rank second with 371 children (39.5 percent) and they hold the same place for children in school and not in school, while they are in third and fourth place respectively for preschool children and those in state hospitals. Speech handicaps rank third, 265 children (28.2 percent) showing them, and communication handicaps fourth with 204 children (21.7 percent). Cerebral palsy is in fifth place, with 143 children (15.2 percent), and orthopedic handicaps follow in sixth place with 92 children (9.8 percent) being afflicted by them. Educational and social deprivation is listed for 74 children (7.8 percent) and epilepsy for 62 children (6.6 percent). The neurological handicaps are listed for only 42 children (4.4 percent) but it can be assumed that more than this number are affected by them and that they are only not listed because no thorough diagnostic evaluation has been done for the large majority of the children. Hearing handicaps show only low numbers (29 children or 3.1 percent) because only mild ones were included, since children with moderate and severe handicaps fall into the deaf-blind category.

Thus, it is apparent that the 940 multihandicapped blind children are a group which shows large numbers of children with mental retardation and emotional difficulties. Communication and speech handicaps also rank high and so do the two handicaps which are most likely to interfere with mobility, cerebral palsy and orthopedic handicaps.

### *Frequency of Handicaps for 240 Deaf-Blind Children*

Table 13 reports the frequency of handicaps for the four groups of deaf-blind children. In this group also, mental retardation ranks first with 165 children (68.8 percent) showing it, almost an equal percentage as shown for the group of multihandicapped blind children. As expected with a group of deaf-blind children, about one half of them have communication and speech handicaps. The numbers and percentages for these two handicaps are not higher because these handicaps cannot be identified in deaf-blind children of preschool age and, among those in school and not in school, some must have lost their hearing after speech was established or their degree of hearing handicap did not interfere with their ability to communicate and speak. Emotional handicaps come immediately after mental retardation and those handicaps which are connected with deaf-blindness, 42 (17.5 percent) of the children showing them. This is a far lower percentage than shown for multihandicapped blind children (39.5 percent). It may be due in part to the fact that deaf-blind children without speech can often not be identified as being emotionally disturbed, and their behavior is ascribed to their deaf-blindness. For the deaf-blind group, in contrast to multihandicapped blind children, heart abnormalities rank far higher, with 35 children (14.6 percent), largely of preschool age, being affected by them. This is, of course, a result of maternal rubella which is the main cause of blindness for the 129 deaf-blind children of preschool age. Cerebral palsy and orthopedic handicaps rank next with 33 (13.8 percent) and 31 deaf-blind children (12.9 percent) respectively having these handicaps which interfere in varying degrees with mobility.

## Conclusions

The tables presented and discussed are based on replies recorded on questionnaires by teachers, preschool workers, or supervisors who are familiar with the children whose characteristics they reported. Their evaluation of the severity of a child's handicap is by necessity subjective since there are no objective measures available. This also holds true, though to a lesser degree, for the enumeration of the handicaps for each child. Distinctions of these kinds are difficult not only because of the subjectivity of the reporters but also because children often are "borderline cases" even to those who are professionally fully qualified to make these judgments. In addition, many children have not been given the needed opportunities which would have challenged and developed their potential. Nevertheless, the method followed in this questionnaire study, and also used by others, is at present the only way to secure badly needed and reasonably accurate data. The pretesting of the questionnaires with personnel of the California School for the Blind and its positive results confirm the high degree of validity of the method used.

In any attempt to project the number of multihandicapped blind children to be expected in the foreseeable future, the causes of blindness must receive first consideration.

For the group of multihandicapped blind children of school age, retrolental fibroplasia is the largest single cause of blindness, 245 (30 percent) of 808 children being affected by it. Retrolental fibroplasia is now reasonably well under control although 13 (10 percent) of the 132 multihandicapped blind children of preschool age still show it as their cause of blindness. Therefore, it must be assumed that maximally

30 percent of the present multihandicapped blind children population of school age would not have existed without retrolental fibroplasia and will not recur in future generations. This still leaves at least 70 percent, or 563 children, with blindness and multiple handicaps as the basis for future projections.

A further factor contributing to the increase of multihandicapped blind children is to be found in a change of causes of blindness that occurred during the past two or three decades. Prenatal causes of blindness, many of which affect not only the eye but also cause additional abnormalities, have increased; and such other causes as infectious diseases and accidents, many of which affect only the eye and leave the child's other sensory, intellectual and physical capabilities intact, have decreased.

In 1945/46, prenatal causes constituted 58.1 percent of all causes of blindness for school age children. Hatfield (*Sight Saving Review*, Winter, 1963; reprint, p. 5) states in the latest study of causes of blindness in school children: "Actually, if cases of blindness due to retrolental fibroplasia are excluded, it is found that 71 percent of the remaining 5,196 cases were due to prenatal influence and 29 percent to other causes." Therefore, prenatal influences have increased by 22.2 percent. On the other hand, again excluding retrolental fibroplasia, infectious diseases have decreased from 19.8 percent to 6.0 percent and injuries from 6.6 to 3.6 percent. This is a decrease of 70 percent for infectious diseases and 45 percent for injuries.

This increase in prenatal causes and decrease in infectious diseases and injuries contributes to the increase in multihandicapped blind children and to the decrease in blind children with no other handicaps. This trend will most likely continue in the foreseeable future.

The increase in population in California must also be considered as a factor and may well make up for the reduction resulting from the control of retrolental fibroplasia. Therefore, any plans for future provisions for multihandicapped blind children must be based on the fact that comparatively large numbers of these children will continue to need educational facilities.

In projecting the number of deaf-blind children, the causes of blindness in deaf-blind children of preschool age must receive first consideration. The predominant role of rubella as a causative factor of deaf-blindness and concomitant cardiac and other abnormalities has been noted. It was also stated that the three-year period between 1964 and 1966 includes the birth years for the large majority of these children. The German measles epidemic between 1964 and 1966 has not only produced unexpected large numbers of deaf-blind children but also resulted in a "massive increase in the number of deaf babies" referred for instance to the San Francisco Hearing and Speech Center for special help (*Bulletin* of the San Francisco Hearing and Speech Center, October, 1967). Rubella epidemics occur in six-to-seven-year cycles and our data in Table 6A show that between 1958 and 1960 also, a considerable number of deaf-blind children were born. These two peak periods are six to seven years apart.

The questions now arise when the next rubella epidemic must be expected and whether by that time an effective vaccine will be available and applied. To reply to the last question first, there is already a vaccine in existence that can be given to nonpregnant, susceptible women of childbearing age. Pilot studies on its effectiveness are being conducted. *Time* magazine (April 5, 1968) reports that "thousands of doses of rubella vaccine, not yet available in the U.S.," have been flown to Taiwan which is presently experiencing another rubella outbreak and a threatened epidemic. It is hoped that these vaccines will be instrumental in avoiding the epidemic. The article also reports that a rubella vaccine "will probably be licensed in Europe by year's end, though U.S. approval will take longer."

The next epidemic of rubella in the United States is to be expected in 1970/71. One can hope that an effective vaccine will be approved in time to prevent a future epidemic in the United States. It must be doubted, however, that such a vaccine, even if available, will completely prevent the effects of an epidemic because it may not have been universally applied to the susceptible population in a comparatively short period of time. If the vaccine is licensed in the United States in 1969, only one to two years will be available for its distribution. Thus, one must realistically count on additional numbers of multihandicapped blind children to be born during the next rubella epidemic. These children will be of preschool or school age for the subsequent eighteen years, that is at least until about 1988/89. They will be added to those born during the rubella epidemic of 1964/66 who will be in school at least until 1984. Additionally, it must be kept in mind that presently unknown factors may exert an influence, as rubella epidemics did when hopes were high that the control of retrolental fibroplasia will lead to a decrease in the number of blind and multihandicapped blind children.

To summarize, an analysis of the causes of blindness for multihandicapped blind children and for deaf-blind children shows that no considerable decrease in their numbers can be expected within the foreseeable future. The control of retrolental fibroplasia did not affect more than 70 percent of multihandicapped blind children whose handicaps were caused by genetic, prenatal, and disease factors which remain as yet uncontrolled. Maternal rubella has caused an appalling increase in the number of deaf-blind children who are at the present largely of preschool age. Even if rubella is controlled within the near future, these children, and possibly others resulting from an expected rubella epidemic in the early 1970s, will be of school age for 12 to 18 years. On the other hand, the numbers of blind children without additional handicaps have decreased considerably and will continue to do so if present trends persist. Therefore, any planning for educational provisions for blind children must take into consideration that the majority of blind children will not be "normal" blind children as we know them from the past but blind children with multiple handicaps and deaf-blind children, as we have come to know them in large numbers for the present. This should not obscure the fact that there are still many "normal" blind children nor the necessity of providing educational opportunities for them which will safeguard their right to develop their potential to the fullest.*

## 2. RECOMMENDATIONS FOR SERVICES NEEDED BY MULTIHANDICAPPED BLIND CHILDREN IN CALIFORNIA (A BLUEPRINT)

In order to explore the thoughts and opinions held by knowledgeable people concerned with the education of blind and multihandicapped blind children in California, many conferences were held with educators, administrators of schools and agencies, parents and parent-group representatives, medical experts, workers with blind preschool children, representatives of the alumni of the California School for the Blind, and representatives of the California State Department of Education, Division of Special Schools and Services. In these conferences, the problems of multihandicapped blind and deaf-blind children were discussed and reactions to the planned proposals for services were explored. The latter were unanimously approving.

### Population to Be Served

Any proposal dealing with provisions for multihandicapped blind children in the State of California must be based on two facts which characterize the fundamental changes that

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**The director of this study is aware that a statistical presentation can only enumerate but not describe the sources of human suffering. He felt this acutely with every tally of the many thousands that he made in the course of this study and was deeply conscious of the heartaches and frustrations which they represent for the many people who are parents of these children and only too often also for the children themselves.*

have occurred in the education of blind children in California.

The first fact is the substantial increase in the number of blind children in the state and the concomitant increase of public school provisions for visually handicapped children. The residential school for the blind in Berkeley has over the past two or three decades shown a stable enrollment of about 160 pupils. The local school enrollment of children who fall within the legal definition of blindness, has during the same period risen from two or three hundred to more than 1,500. California is the state in which by far the largest percentage of visually handicapped children (about 90 percent) attend local schools either with resource or itinerant teachers available. National statistics indicate that about 60 percent of visually handicapped children attend local schools and 40 percent residential schools. As the statistics presented in the first section show, local school provisions have also taken into local classes their share of multihandicapped blind and deaf-blind children.

Of the 1,700 blind children of school age in California, about 1,550 attend local schools and 150 the California School for the Blind. Of the 1,550 blind children in local schools, 433 are multihandicapped and 36 are deaf-blind which leaves a population of 1,081 "normal" blind children. Of the 150 blind children enrolled at the California School for the Blind, 104 are multihandicapped and 16 are deaf-blind which leaves an enrollment of 30 "normal" blind children. Therefore, 1,111 "normal" blind children are enrolled in facilities for blind children in California.

According to the statistics presented (Table 1), 1,180 multihandicapped blind children have been found, of whom 261 are of preschool age. This leaves a population of 919 multihandicapped blind children of school age in the state to which about 1,000 multihandicapped blind children of school age in state hospitals must be added. The 1,217 reported in state hospitals include all children under 21 years of age and we estimate that about 200 of them are of preschool age. It can, therefore, be stated that for the school age population, normal blind children (1,111) outnumber the multihandicapped blind children by 11 to 9. If we include the state hospital population of multihandicapped blind children, multihandicapped blind children of school age (1,919) outnumber "normal" blind children (1,111) by 19 to 11.

Before we come to our discussion of proposed facilities for blind children in California, we have to look at the statistical facts from still another angle. We want to determine how many multihandicapped blind children there are in the state who are at present receiving their education in facilities that cannot serve them adequately and how many are in need of diagnostic services.

According to the statistics presented in Table 1, there are 189 multihandicapped blind children not in school. How many of the 1,217 children in state hospitals who are without any schooling could be helped by educational and/or diagnostic facilities is anybody's guess. There is no doubt that a great number, if not all, of the 132 multihandicapped blind children of preschool age and of the 129 deaf-blind children of preschool age could greatly benefit by more intensive services of preschool workers and by thorough diagnostic examinations. In addition, it must be recognized that many of the 595 multihandicapped blind and deaf-blind children in school and of the 100 such children in state hospital schools receive only minimal educational services which are not conducive to meet their needs and improve their conditions. Thus, it appears that a staggering backlog of educational work for many hundreds of multihandicapped blind and deaf-blind children, who constitute a truly deprived group, needs to be done and done without delay so that the condition of these children will neither become permanent nor worse.

## Preschool Services

At present, preschool services for young blind children are provided in Northern California by four preschool workers under the Variety Club Blind Babies Foundation auspices, and by two preschool workers in Southern California under the California State Department of Education, Division of Special Schools and Services. The state's preschool workers in Southern California have a case load of fifty to seventy families which includes many parents of multihandicapped blind and deaf-blind children. Such a case load permits only the most superficial services, with visits spaced so far apart that no consistent and effective guidance can be given.

These services began in the late 1950s when the number of "normal" blind children was predominant and when blind children of preschool age did not show as many and as severe multihandicapping conditions as are found at present. During the early 1950s when retrolental fibroplasia increased the number of blind preschool children, four preschool workers were on the state's staff, each serving a case load of 35 to 40 children. The four preschool workers were reduced to only two when a decrease in the number of blind children of preschool age occurred due to the control of retrolental fibroplasia. The two positions were transferred to the staff at the California School for the Blind because of the increased enrollment of multihandicapped blind children. So far, the number of state preschool workers has remained at two for budgetary reasons. The Variety Club Blind Babies Foundation had at that time six preschool workers who served Northern California.

The smaller case load made more intensive services possible than are at present rendered in Southern California, the more so because there were many parents and their children who had received intensive services at a younger age so that they did not need frequent visits as they grew older except on occasions of special problems.

The case loads of preschool workers in 1968 include a majority of multihandicapped blind and deaf-blind children who need intensive services far beyond those given to the preschool blind children of earlier years. It is generally recognized that preventive and remedial educational services are most effective when they are rendered at an early age of the child. Therefore, it should be one of the basic tenets of any program for multihandicapped blind children that intensive services must be given during preschool years in order to make the child as capable as his potential permits in the areas of physical and mental development, of self-care, of socializing, and of coping with the effects of his handicaps. This can only be achieved if preschool workers have a case load which will allow them to assist parents and children by frequent visits. For this reason, *it is recommended that a case load of 25 families per preschool worker, with an absolute maximum of 30, be adopted as an essential step of an adequate program serving multihandicapped blind and deaf-blind preschool children. This should be put into effect immediately.*

## Types of Services Needed for School Age Children

When a multihandicapped blind child becomes of school age, a decision concerning his educational placement must be made. This decision can at present only be based on the observations of preschool workers, if they served the child at all; on the reports given by any other professional persons who had contact with the child such as pediatricians, nursery school or kindergarten teachers; and on any personal impressions that a school administrator and his assistants may get from an interview with the parents and the blind child. Experience has shown that such casual observations in many, if not most cases, do not allow for a reliable and tenable conclusion and that many children are admitted only "on trial" to an educational provision which may or may not serve their needs. Many must remain in provisions which do not serve their needs because the alternatives are actually limited to only two kinds of provisions: local or residential schools and state hospitals.

As the first section shows, local and residential schools have large numbers of multihandicapped blind children. Many of them are receiving adequate education in these facilities, but for many of them, neither the local schools nor the residential school in its present setup offer an adequate program. Comments from those working with multihandicapped blind children in local schools stressed that many of them are there only because no other facility is available and that they could greatly improve with more intensive help. A classroom situation where thirty or more children are assigned to one teacher, and six to ten blind children, some of them multihandicapped, to one resource or itinerant teacher, does not allow any effective teaching or training of multihandicapped blind children but amounts in practice to little more than a babysitting situation.

Under the impact of this problem, which is not limited to multihandicapped blind children only, some local schools are planning to conduct diagnostic classes for children with multiple handicaps of all kinds to which some blind children may also be admitted. It must be hoped that these experimental programs will be successful and, if so, that more local schools will provide them. Also, a few school districts have started special classes for multihandicapped children because they recognize that these children do not fit into regular provisions and need different techniques of training and teaching for which a low teacher-pupil ratio would be essential. However, these low teacher-pupil ratios are not put into effect because of the financial consequences involved. Thus, these programs, like regular classes in local schools, are also not much more than a "keeping" operation though they may be helpful to some children whose multihandicapping conditions are not severe.

As out statistics demonstrate, the California School for the Blind now has a large majority of multihandicapped children (about 80 percent). Its staffing pattern has not changed essentially and, because there are some "normal" blind children enrolled, the teachers are forced into a situation where they cannot do justice to either group. Also, the teacher-pupil ratio and the teacher preparation are not such that effective services can be rendered to multihandicapped blind children. Most teachers at the California School for the Blind have been prepared to teach, and for varying numbers of years have successfully taught, blind children of normal intelligence. This does not necessarily make them capable of teaching multihandicapped blind children and some of them are certainly personally not suited for this task. Needless to say that the "normal" blind child is seriously disadvantaged in an environment where multihandicapped blind children predominate.

Fern K. Root, in her article "Evaluation of Services for Multiple-Handicapped Blind Children" (*International Journal for the Education of the Blind*, December, 1963, pp. 33-8), considers which important questions educators must ask who wish to evaluate the effectiveness of services to multihandicapped blind children. She mentions among others the following:

> *Is there a full range of diagnostic services or a comprehensive clinic which provides psychological, developmental, neurological, psychiatric, speech and hearing and other special evaluations?*
>
> *Who assumes responsibility for helping parents follow through recommendations?*
>
> *Are there local or state-sponsored educational programs to which multiple-handicapped blind children may be referred if they are able to profitably participate in academic activities?*
>
> *Are there local or regional training, treatment and custodial facilities for multiple-handicapped blind children who are not able to profit from the instructional program of the schools?*
>
> *Are there provisions for long-term counseling to parents whose multiple-handicapped blind children have received adequate medical and diagnostic service and educational placement, but whose special problems are so severe that permanent educational placement is infeasible?*

So far as the State of California is concerned, we must answer:

There are no diagnostic services available except the medically-oriented ones.

There are no treatment facilities available for those who are not able to profit from the instructional programs of local or residential schools.

There are neither short-term nor long-term counseling facilities for parents available.

In order to provide services for multihandicapped blind children in California, the following facilities are needed:

1. A diagnostic center to which multihandicapped blind children can be referred from all parts of the state in order to receive a complete medical evaluation of their conditions, if it is not already available, and to receive a functional educational diagnosis which will lead to definite recommendations concerning their placement.
2. Training and adjustment centers for multihandicapped blind children should be established. At present, any recommendations even if based on a diagnostic workup have only two extremes from which to choose: placement in local or residential facilities or commitment to a state hospital. The proposed training and adjustment centers should provide a remedial facility where multihandicapped blind children can receive intensive help in order to achieve a level that would either enable them to return to their families and attend local schools; to remain in the center until they are ready to be

served by vocational rehabilitation, a sheltered workshop, or by other arrangements that the families will make; or if at any age further improvement cannot be achieved, they will be returned to their families with their self-care skills improved according to their capabilities. This will be a great asset to them whether they remain with their families, be placed in a private institution, or committed to a state hospital.

3. Guidance and counseling services to parents of multihandicapped blind and deaf-blind children of school age, in order to improve their ability to fulfill their parental responsibilities toward the multihandicapped blind or deaf-blind child and to accept and pursue the placement recommendations made by the diagnostic center or the training and adjustment centers.

## Recommendations for Establishing the Needed Services

The only residential educational facility for blind children in California is the California School for the Blind in Berkeley. It consists of an administration and school building, a dormitory building for boys (Wilkinson Hall), a dormitory building for girls (Vista del Mar), a dormitory building for young children (Monroe Cottage) with an instructional center for the deaf-blind (Helen Keller Building), a gymnasium building (built in 1915), and a dining hall-kitchen building. All of these buildings with the exception of the deaf-blind center and the dining hall-kitchen building were built at least 40 years ago. So far as the buildings are concerned, the dormitory for boys is designed in such a way that it makes living arrangements, supervision, and janitorial services extremely difficult and expensive because of the extension of the building from one end to the other, and because of its very disadvantageous two-story arrangement. It fits beautifully into the landscape but it is unsuitable for the purposes it has to serve. Similar observations can be made for the residence building of the young children (Monroe Cottage and Helen Keller Building). The Helen Keller Building has a residence facility for sixteen young children, built in 1950, which is adequate, but cannot be combined with the residence facility at Monroe Cottage. Therefore, both facilities demand separate staffing at a high cost. All buildings are expensive to maintain. With the exception of the two above-mentioned buildings, they must be considered obsolete.

The grounds on which all buildings are located are at different levels and it is no exaggeration to say that they represent, together with the buildings, a concentrated example of architectural barriers. There are steps going up and down from all buildings, some of them very difficult to locate; there are curves and corners in all sidewalks connecting the buildings with variations in levels, particularly before the stairs are reached. Commuting between the different buildings and especially between the residence halls and the dining room and the residence halls and the school building is difficult even for well-oriented blind children and a health hazard for all children, particularly the younger ones, in inclement weather.

These disadvantages were less acutely felt during the time when normally capable blind boys and girls constituted a majority of the students. They make the buildings unsuitable and hazardous for use of multihandicapped blind children. As a matter of fact, over the years the school had to refuse admission to many capable visually handicapped children who suffered from an orthopedic defect or from cerebral palsy because these handicaps interfered with their mobility in this difficult terrain.

For these reasons, and for others which will become clear with the subsequent presentation of the planned services for multihandicapped blind children, *it is recommended that the site and buildings of the California School for the Blind should be given up for the purpose they presently serve and should be used for other purposes.*

It is not the task of this study to deal with the latter problem, but the following tentative suggestions for the use of this facility might be in place: expansion of the California School for the Deaf which has a considerable waiting list; sale to a private school; sale to the University of California (including the hilly area above both schools--the University of California Medical School in San Francisco is built on similarly steep grounds); sale to land developers (the property constitutes the most valuable piece of land in Berkeley). In any case, the value of the property is such that it should cover a substantial part of the costs of the subsequently developed plan for services to blind children.

## "Normal" Blind Children at the California School for the Blind

The following recommendations will deal with the conversion of the present California School for the Blind into comprehensive services for multihandicapped blind children. Therefore, the group of "normal" blind children and of those multihandicapped blind children who are capable of attending regular educational provisions--all of them now placed at the California School for the Blind--must receive consideration. *It is recommended that as many of them as possible be placed in local facilities.* There are essentially three means to achieve this:

1. Children whose parents live in communities where local facilities for blind children are available should be induced to, and assisted in, having their children return home and placed in the local schools.

2. There are some counties which, if they would combine with others, have a sufficient number of blind children to conduct a program for them either by a resource or itinerant teacher arrangement. The State Department of Education should encourage such multicounty arrangements and assist them so that they will not be a financial burden on the counties concerned. The Division of Special Schools and Services could provide itinerant teachers to serve visually handicapped high school students in local schools throughout the state.

3. There will remain a small number of children who cannot be returned to their families for individual reasons, such as that the families are not a good place for them, or that they are not yet ready to be placed in a local school without more intensive personal care. For these children, either foster home placement in a community with local provisions for blind children, or a small residential unit, the location of which will be discussed later, should be made available.

## DIAGNOSTIC CENTER

The diagnostic center, considered a necessity by all those consulted in the course of this study and also described as such in various articles, should be a separate unit serving about 40 to 50 multihandicapped blind children. Referrals would be accepted from any source that is qualified and in a position to justify a child's need for a diagnostic observation. Children should remain at this center for as long a time as is reasonably required to arrive at a diagnosis and at recommendations for the child's future placement. Cruickshank, in recommending the establishment of residential diagnostic centers for multihandicapped blind children in his article "The Multiple-Handicapped Child and Courageous Action" *(International Journal for Education of the Blind,* March, 1964, pp. 74-5), urges: ". . . residential diagnostic centers of a relatively short-term duration wherein the complete skills of many diagnosticians can be brought to bear on the complicated physical, psychological, and educational problems of these children. In a sense we are advocating the establishment in this area of what has apparently been a successful model in California, namely, the diagnostic residential centers of that state for cerebral palsy."

Such a center must be placed within a reasonable distance from a medical center so that its specialists can be available to the center as consultants. "Diagnosticians representing many disciplines will be required, in addition to ophthalmology which is usually represented in a table of organization of a residential school. Pediatric psychiatrists, clinical psychologists with a specialty in the childhood years, pediatricians, pediatric neurologists, otologists and audiologists, endrocrinologists, and educators with broad special education experience will all be needed at some phase of the program" (Cruickshank, *ibid.*, p. 69).

Full-time positions in such a center must include: educators who work with the children in small groups either two to three for one teacher or four to six for two teachers; dormitory personnel who must be trained educators so that they can continue the work of the teachers in the dormitory situation; psychologists; and social case workers. The psychologists and social workers will function not only as members of the diagnostic team but will also obtain information from the parents and will assist them in better understanding themselves and their child and in more adequately meeting his needs. The center should also have short-term residential facilities for parents of children to be admitted, so that they will be available for interviews and during their child's first days at the center.

Staffing and administration of such a diagnostic center is not a new task for the Division of Special Schools and Services. This division has carried the same responsibility for the diagnostic centers for cerebral palsied children and carries it now for the two diagnostic centers for neurologically handicapped children. The patterns established, particularly for the last-mentioned ones, can readily be applied to the recommended diagnostic center for multihandicapped blind children.

## Training and Adjustment Centers (T and A Centers)

Two training and adjustment centers with a capacity of from 50 to 80 children each should be established, one in Northern California and one in Southern California.

These T and A centers should have the same function as a residential school for the blind, except that they should be geared in purpose, methods, and staffing to the needs of multihandicapped blind children. The purpose should be to rehabilitate as many children as possible for return to local schools. For those who cannot be returned, opportunities should be provided for developing their nonacademic potential in self-care, social skills, mobility, occupational skills, and in acquiring a workable knowledge of the world in which they must live. Thus, the T and A center will function for some as a temporary rehabilitation facility, and for others as a continuing residential placement until they have reached an age when adult rehabilitation services can take over. It must be expected that some of the children referred to these centers will, in spite of all efforts, not be able to function anywhere but in an institutional environment. These children should be returned to their families and recommendations for their future should be explained to the parents who will have to make the ultimate decisions.

Methods in these T and A centers should fit their purpose. Mental retardation is the most frequent multihandicapping condition. For these children academic studies are less important than developing their potential in self-care, social skills, mobility, occupational skills, and in learning about the world around them. There are some children who are emotionally disturbed, orthopedically handicapped, or cerebral palsied whose mental capacity is normal or superior. For them, adequate academic training should be provided.

The staffing of the T and A centers should essentially be the same as that desirable for a residential school for the blind, with a full-time physiotherapist added. It will require a low teacher-pupil ratio, one teacher for three to four children, or better, two teachers for six to eight children. This should be the actual ratio for classroom work. In addition, special teachers in certain other fields will be required, such as mobility instruction, crafts, physical education, music, and homemaking. The dormitory personnel should be trained in working with exceptional children so that gains made by the teachers will be followed up, and not lost, in the dormitory situation. Therefore, the dormitory personnel-children ratio should be about one to five, the former actually present at any time during the day. For nighttime duty, an attendant can supervise a much larger number of (sleeping) children.

The purposes and functions of a T and A center are well recognized by the Superintendent of the California School for the Blind and by many of its staff members who had in the past years abundant experience with multihandicapped blind children. The California School for the Blind, however, was never designed nor was it ever staffed to serve this group of children.

## Guidance and Counseling Services

As already described, these services to parents of multihandicapped blind and deaf-blind children of school age should be established. They should serve the parents of children admitted to the diagnostic center and to the T and A centers. It is recommended that one social worker be assigned to each of the three centers to meet this need. If the population in any of these centers should rise above forty, an additional social worker should be allowed.

## Deaf-Blind Center

Federal legislation has already been passed to establish regional centers for deaf-blind children and a national center for deaf-blind youths and adults. These centers have not yet been financed in the federal budget but the United States Office of Education has already undertaken steps to plan for the establishment and conduct of such centers. There is no doubt that the California School for the Blind will be one of the regional centers and that federal support will be forthcoming for the construction, as well as the operation of this center. The present facility for deaf-blind children at the California School for the Blind cannot serve more than about 16 deaf-blind children. Although some of the 129 deaf-blind children of preschool age reported in the study may go to local schools, the majority of them will need residential placement for diagnostic purposes as well as for their education. They are deaf-blind as a result of maternal rubella and, therefore, more severely multihandicapped and, thus, less likely to be able to attend any local school.

## Locations

It is recommended that the diagnostic center, one of the T and A centers, the deaf-blind center, and, if established, the residential unit for "normal" blind children attending nearby local schools, be established as one "educational park" for visually handicapped children. The advantages for such a combination are obvious. One superintendent and the necessary administrative staff could serve all components; one central kitchen with a number of small dining halls attached could serve the whole population; consultant staff members could be available to each component when needed; recreational facilities, such as gymnasium, swimming pool, playfields, could serve all components to be used at prearranged times; specialized staff, such as mobility instructors, psychologists, social workers, physical-occupational therapists could be shared by all components; exchanges of staff members according to skills and preferences could be arranged; and social work services for parents of preschool age children and of school age children could be rendered from this location with office space and secretarial assistance available to them. For the social workers serving preschool and school age children, this would be a great advantage because they could coordinate their services.

If it should be decided to locate this "educational park" in Northern California, within reasonable reach of a comprehensive medical facility such as the University of California Medical School, another T and A center should be established in Southern California. If the "educational park" should be located in Southern California, also in the vicinity of a medical center, a T and A center should be established in Northern California.

## Plans for the Interim Period

It is recognized that even with the promptest response of all concerned, considerable time will be needed for a transition from the present status to that recommended in this study. Legislation might be needed and budgetary provisions will need to be made and approved. Also, the actual planning and building of the new facilities will require time. For this reason, it is necessary to suggest some ways of meeting the present acute needs of the population described in this study. It is suggested that:

1. Additional preschool workers be allowed as a part of the next budget of the California School for the Blind. As already indicated, one preschool worker should serve 25 to maximally 30 families in which a blind child of preschool age grows up.
2. Additional teachers as well as counselors be provided for the presently enrolled children at the California School for the Blind. The teacher-pupil ratio should be set at 1 to 5 for classroom enrollment, with teachers required for such subjects as physical education, music, crafts, and so forth added. So far as counselors are concerned, the recommendations of the Child Welfare League of America in *Standards for Services of Child Welfare Institutions* seems well applicable. They recommend: "Normally there should be at least one adult, with no other major responsibilities, to six children." In applying this ratio, variations according to age and special problems, such as deaf-blindness, must receive consideration. The increase in teaching and counseling staff would not only assist in meeting current needs but would also provide trained personnel for the planned facilities. A corresponding increase in supervisory personnel for the teaching staff and for the counselor staff should also be allowed.
3. Some long-needed additions to the staff should be provided to assist in the management of problems of multihandicapped blind children: a clinical psychologist, increased psychiatric consultation, a social worker to work with parents, additional mobility instructors, and a part-time physiotherapist.
4. Teacher education facilities should be made aware of the increased employment opportunities in the field of multihandicapped blind children so that they can increase their efforts in recruiting and educating the needed personnel.
5. Teacher education institutions need to make further provisions for the education of teachers of multihandicapped children, including the multihandicapped blind, so that this

large and increasing group of children can be educated by more adequately prepared educators.

6. Changes in the credentialing of teachers in special education should be made so that the unrealistic division of credentials by dominant handicaps is supplemented or replaced by a credential for the teaching of multihandicapped children.

## CONCLUSIONS

The people of California, through their legislative representatives, and the California State Department of Education have always shown understanding and compassion for handicapped children. They have built for them in the past years a completely new School for the Deaf in Riverside, a Diagnostic Center for Cerebral Palsied Children in Northern California and another one in Southern California (both are now functioning as diagnostic centers for neurologically handicapped children), and they have built a completely new plant to replace the old California School for the Deaf in Berkeley. It must be hoped that in this hour of urgent need, they will not fail the hundreds of multihandicapped blind children who depend upon them for an immediate solution which will provide for them an education suited to their needs or in other words equality of educational opportunity.

## Table 1

### Multihandicapped Blind Children in California

| | *N* | |
|---|---|---|
| Multihandicapped blind children in school | 537 | |
| Multihandicapped blind children in state hospital schools | 82 | |
| Multihandicapped blind children (school age) *not* in school | 189 | |
| Multihandicapped blind children of preschool age | 132 | |
| Total, multihandicapped blind children | | 940 |
| Deaf-blind children in school | 58 | |
| Deaf-blind children in state hospital schools | 18 | |
| Deaf-blind children (school age) *not* in school | 35 | |
| Deaf-blind children of preschool age | 129 | |
| Total, deaf-blind children | | 240 |
| TOTAL | 1,180 | |
| Visually handicapped patients 21 years or under in state hospitals (100 additional accounted for in lines 2 and 6): | 1,217 | |

## Table 2A

## 537 Multihandicapped Blind Children in School

| | | | |
|---|---|---|---|
| *Year of Birth* | | | |
| | *N* | | *N* |
| 1962 | 11 | 1953 | 79 |
| 1961 | 12 | 1952 | 51 |
| 1960 | 28 | 1951 | 40 |
| 1959 | 40 | 1950 | 36 |
| 1958 | 39 | 1949 | 13 |
| 1957 | 35 | 1948 | 8 |
| 1956 | 47 | 1947 | 6 |
| 1955 | 42 | not reported | 2 |
| 1954 | 48 | | |
| *Grade Placement* | | | |
| Kg | 9 | 9 | 23 |
| 1 | 18 | 10 | 18 |
| 2 | 22 | 11 | 5 |
| 3 | 20 | 12 | 6 |
| 4 | 33 | Primary | 5 |
| 5 | 29 | Junior high | 4 |
| 6 | 29 | High school | 6 |
| 7 | 21 | Ungraded | 239 |
| 8 | 25 | Not reported | 25 |
| *Visual Acuity* | | | |
| No vision | 110 | 20/200 | 60 |
| LP | 70 | 20/200 - 20/60 | 81 |
| Some | 7 | Partial | 15 |
| Blind | 147 | Not reported | 47 |
| *Cause of Blindness* | | | |
| RLF | 168 | Retinitis pigmentosa | 4 |
| Cataracts | 57 | Brain damage | 6 |
| Optic atrophy | 42 | Aphakia | 4 |
| Myopia | 26 | Retinal degeneration | 3 |
| Congenital | 22 | Microphthalmos | 3 |
| Glaucoma | 19 | Uveitis | 3 |
| Anophthalmos | 14 | Meningitis | 3 |
| Nystagmus | 10 | Retinal detachment | 3 |
| Macular degeneration | 10 | Brain tumor | 3 |
| Albinism | 9 | Amblyopia | 3 |
| Rubella | 7 | Various | 50 |
| Chorioretinitis | 5 | Not reported | 63 |
| *School Placement* | | | |
| Local schools | 433 | California School for the Blind | 104 |

## Table 2B

## 537 Multihandicapped Blind Children in School

| *Handicap* | *Edu-cable* | *Train-able* | *Unedu-cable* | *Degree Not Reported* | *Total* |
|---|---|---|---|---|---|
| Mental | 170 | 121 | 16 | 43 | 350 |
| | Mild | Moder-ate | Severe | | |
| Hearing | 16 | -- | -- | 4 | 20 |
| Communication | 11 | 18 | 18 | 26 | 73 |
| Speech | 40 | 31 | 28 | 44 | 143 |
| Cerebral palsy | 16 | 23 | 9 | 28 | 76 |
| Orthopedic | 11 | 10 | 12 | 15 | 48 |
| Epilepsy | 12 | 7 | 3 | 11 | 33 |
| Emotional | 55 | 61 | 51 | 47 | 214 |
| Educational | -- | -- | -- | 58 | 58 |
| Sociocultural | -- | -- | -- | 10 | 10 |
| Neurological | -- | -- | -- | 9 | 9 |
| Heart | -- | -- | --- | 7 | 7 |
| Coordination | -- | -- | -- | 5 | 5 |
| Bilingual | -- | -- | -- | 5 | 5 |
| Various | -- | -- | -- | 35 | 35 |
| Total | 331 | 271 | 137 | 347 | 1,086 |
| Percent | 30.5 | 24.9 | 12.7 | 31.9 | |

*Number of Handicaps in Addition to Blindness*

| Handicaps | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | 244 | 145 | 77 | 45 | 16 | 9 | 1 |

Average number of handicaps per child (including blindness): 3.0

*Recommendations for Future Placement*

| | |
|---|---|
| Remain | 370 |
| Should not remain | 35 |
| Not reported | 132 |

## Table 2C

## County Distribution

---

*537 Multihandicapped Blind Children in School*

---

| | |
|---|---|
| CSB | 104 |
| Alameda | 26 |
| Butte | 1 |
| Colusa | 1 |
| Contra Costa | 12 |
| Del Norte | 1 |
| Fresno | 8 |
| Glenn | 4 |
| Imperial | 1 |
| Kern | 9 |
| Los Angeles | 175 |
| Madera | 3 |
| Marin | 5 |
| Mendocino | 2 |
| Napa | 3 |
| Orange | 12 |
| Riverside | 7 |
| Sacramento | 25 |
| San Bernardino | 18 |
| San Diego | 16 |
| San Francisco | 31 |
| San Joaquin | 15 |
| San Mateo | 9 |
| Santa Barbara | 3 |
| Santa Clara | 10 |
| Shasta | 2 |
| Siskiyou | 1 |
| Solano | 3 |
| Sonoma | 5 |
| Stanislaus | 8 |
| Tulare | 2 |
| Ventura | 8 |
| Yolo | 7 |

## Table 3A

## 82 Multihandicapped Blind Children in State Hospital Schools

*Year of Birth*

|  | *N* |  | *N* |
|---|---|---|---|
| 1963 | 1 | 1954 | 11 |
| 1962 | 1 | 1953 | 12 |
| 1961 | 2 | 1952 | 9 |
| 1960 | 1 | 1951 | 7 |
| 1959 | 5 | 1950 | 6 |
| 1958 | 4 | 1949 | 6 |
| 1957 | 1 | 1948 | 3 |
| 1956 | 2 | not reported | 3 |
| 1955 | 8 |  |  |

*Grade Placement*

| | |
|---|---|
| Ungraded | 82 |

*Visual Acuity*

| | |
|---|---|
| No vision | 21 |
| LP | 4 |
| Some | 1 |
| Blind | 46 |
| Not reported | 10 |

*Cause of Blindness*

| | |
|---|---|
| RLF | 29 |
| Cataracts | 7 |
| Glaucoma | 3 |
| Anophthalmos | 2 |
| Trauma | 3 |
| Rubella | 2 |
| Various | 10 |
| Not reported | 26 |

## Table 3B

## 82 Multihandicapped Blind Children in State Hospital Schools

| *Handicap* | *Educable* | *Trainable* | *Uneducable* | *Degree Not Reported* | *Total* |
|---|---|---|---|---|---|
| Mental | 13 | 64 | 2 | 3 | 82 |
| | Mild | Moderate | Severe | | |
| Hearing | -- | -- | -- | -- | -- |
| Communication | 1 | 23 | 9 | 5 | 38 |
| Speech | 5 | 14 | 13 | 7 | 39 |
| Cerebral palsy | -- | -- | 3 | 4 | 7 |
| Orthopedic | 3 | 2 | -- | 2 | 7 |
| Epilepsy | -- | 1 | 2 | 3 | 6 |
| Emotional | 3 | 5 | 7 | 5 | 20 |
| Psychotic reaction | -- | -- | -- | 6 | 6 |
| Encephalopathy | -- | -- | -- | 10 | 10 |
| Environmental | -- | -- | -- | 1 | 1 |
| Cerebral lipoidosis | -- | -- | -- | 1 | 1 |
| Mongolism | -- | -- | -- | 2 | 2 |
| Total | 25 | 109 | 36 | 49 | 219 |
| Percent | 11.4 | 49.8 | 16.4 | 22.4 | |

*Number of Handicaps in Addition to Blindness*

| Handicaps | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| *N* of children | 13 | 27 | 20 | 19 | 2 | 1 | - |

| | |
|---|---|
| Average number of handicaps per child (including blindness): | 3.7 |

## Table 4A

### 189 Multihandicapped Blind Children (School Age) Not in School

*Year of Birth*

| | N | | N |
|---|---|---|---|
| 1961 | 7 | 1953 | 17 |
| 1960 | 9 | 1952 | 22 |
| 1959 | 7 | 1951 | 15 |
| 1958 | 8 | 1950 | 12 |
| 1957 | 15 | 1949 | 15 |
| 1956 | 14 | 1948 | 12 |
| 1955 | 7 | 1947 | 3 |
| 1954 | 20 | not reported | 6 |

*Visual Acuity*

| | |
|---|---|
| No vision | 59 |
| LP | 26 |
| Some | 23 |
| Blind | 24 |
| 20/200 | 12 |
| Partial | 9 |
| Not reported | 36 |

*Cause of Blindness*

| | | | |
|---|---|---|---|
| RLF | 48 | Macular degeneration | 4 |
| Optic atrophy | 12 | Microphthalmos | 4 |
| Congenital | 11 | Trauma | 4 |
| Glaucoma | 11 | Hydrocephalos | 3 |
| Cataract | 9 | Rubella | 2 |
| Brain damage | 5 | Various | 21 |
| Nystagmus | 4 | Not reported | 51 |

*Placement*

| | |
|---|---|
| Home | 115 |
| Home (left school) | 60 |
| Not reported | 14 |

## Table 4B

## 189 Multihandicapped Blind Children (School Age) Not in School

| *Handicap* | *Educable* | *Trainable* | *Uneducable* | *Degree Not Reported* | *Total* |
|---|---|---|---|---|---|
| Mental | 15 | 39 | 17 | 59 | 130 |
| | Mild | Moderate | Severe | | |
| Hearing | 4 | -- | -- | 2 | 6 |
| Communication | -- | 6 | 12 | 10 | 28 |
| Speech | 3 | 4 | 11 | 16 | 34 |
| Cerebral palsy | 4 | 3 | 4 | 25 | 36 |
| Orthopedic | 2 | 5 | 3 | 9 | 19 |
| Epilepsy | -- | 3 | 1 | 7 | 11 |
| Emotional | 2 | 14 | 28 | 40 | 84 |
| Neurological | -- | -- | -- | 21 | 21 |
| Sociocultural | -- | -- | -- | 5 | 5 |
| Autism | -- | -- | -- | 2 | 2 |
| Brain damage | -- | -- | -- | 4 | 4 |
| Heart | -- | -- | -- | 2 | 2 |
| Various | -- | -- | -- | 4 | 4 |
| Total | 30 | 74 | 76 | 206 | 386 |
| Percent | 7.8 | 19.2 | 19.7 | 53.3 | |

*Number of Handicaps in Addition to Blindness*

| Handicaps | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| *N* of children | 84 | 59 | 19 | 15 | 7 | 3 | 2 |

Average number of handicaps per child (including blindness): 3.0

## Table 4C

## County Distribution

| *189 Multihandicapped Blind Children (School Age) Not in School* | |
|---|---|
| Alameda | 5 |
| Butte | 1 |
| Contra Costa | 3 |
| Fresno | 6 |
| Glenn | 1 |
| Humboldt | 1 |
| Imperial | 1 |
| King | 1 |
| Kern | 2 |
| Los Angeles | 58 |
| Madera | 1 |
| Marin | 3 |
| Mendocino | 2 |
| Merced | 1 |
| Orange | 8 |
| Riverside | 3 |
| Sacramento | 5 |
| San Bernardino | 3 |
| San Diego | 4 |
| San Francisco | 14 |
| San Luis Obispo | 4 |
| San Mateo | 1 |
| Santa Barbara | 1 |
| Santa Clara | 8 |
| Shasta | 1 |
| Siskiyou | 2 |
| Solano | 1 |
| Sonoma | 3 |
| Stanislaus | 1 |
| Tulare | 1 |
| Ventura | 3 |
| Yolo | 5 |
| Yuba | 2 |
| Not reported | 33 |

## Table 5A

## 132 Multihandicapped Blind Children of Preschool Age

*Year of Birth*

| | *N* | | *N* |
|---|---|---|---|
| 1960 | 4 | 1965 | 27 |
| 1961 | 6 | 1966 | 13 |
| 1962 | 24 | 1967 | 6 |
| 1963 | 26 | 1968 | 1 |
| 1964 | 24 | Not reported | 1 |

*Visual Acuity*

| | |
|---|---|
| No vision | 21 |
| LP | 27 |
| Some | 16 |
| Blind | 6 |
| Partial | 14 |
| Not reported | 48 |

*Cause of Blindness*

| | |
|---|---|
| Rubella | 28 |
| RLF | 13 |
| Cataracts | 11 |
| Optic atrophy | 9 |
| Cortical deficiency | 5 |
| Glaucoma | 5 |
| Brain damage | 4 |
| Hydrocephalos | 4 |
| Congenital | 3 |
| Meningitis | 3 |
| Macular degeneration | 3 |
| Various | 32 |
| Not reported | 12 |

*Placement*

| | | | |
|---|---|---|---|
| Home | 51 | DCHM | 5 |
| Blind children's center | 33 | State hospitals | 4 |
| Preschool | 15 | Not reported | 23 |
| Orthopedic school | 1 | | |

## Table 5B

## 132 Multihandicapped Blind Children of Preschool Age (excluding deaf-blind)

| *Handicap* | *Educable* | *Trainable* | *Uneducable* | *Degree Not Reported* | *Total* |
|---|---|---|---|---|---|
| Mental | 12 | 29 | 14 | 47 | 102 |
| | Mild | Moderate | Severe | | |
| Hearing | 3 | -- | -- | -- | 3 |
| Communication | 7 | 8 | 31 | 19 | 65 |
| Speech | 3 | 6 | 23 | 17 | 49 |
| Cerebral palsy | 3 | 1 | 5 | 15 | 24 |
| Orthopedic | 2 | 1 | 5 | 10 | 18 |
| Epilepsy | 5 | 2 | 2 | 3 | 12 |
| Emotional | 6 | 12 | 17 | 18 | 53 |
| Heart | -- | -- | -- | 9 | 9 |
| Cleft palate | -- | -- | -- | 4 | 4 |
| Neurological | -- | -- | -- | 2 | 2 |
| Various | -- | -- | -- | 10 | 10 |
| Total | 41 | 59 | 97 | 154 | 351 |
| Percent | 11.7 | 16.8 | 27.6 | 43.9 | |

*Number of Handicaps in Addition to Blindness*

| Handicaps | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| *N* of children | 35 | 30 | 29 | 26 | 8 | 3 | 1 |

Average number of handicaps per child (including blindness): 3.7

## Table 5C

## County Distribution

| *132 Multihandicapped Blind Children of Preschool Age (excluding deaf-blind)* | |
|---|---|
| Alameda | 9 |
| Contra Costa | 5 |
| Humboldt | 1 |
| Imperial | 1 |
| Kern | 3 |
| Los Angeles | 71 |
| Marin | 1 |
| Merced | 2 |
| Napa | 1 |
| Orange | 1 |
| Sacramento | 3 |
| San Diego | 2 |
| San Francisco | 5 |
| San Joaquin | 2 |
| San Luis Obispo | 3 |
| San Mateo | 4 |
| Santa Barbara | 1 |
| Santa Clara | 7 |
| Santa Cruz | 1 |
| Solano | 1 |
| Sonoma | 1 |
| Stanislaus | 1 |
| Sutter | 1 |
| Tehama | 1 |
| Tulare | 1 |
| Yolo | 1 |
| Not reported | 2 |

## Table 6A

## 58 Deaf-Blind Children in School

*Year of Birth*

| | N | | N |
|---|---|---|---|
| 1962 | 1 | 1955 | 1 |
| 1961 | 3 | 1954 | 5 |
| 1960 | 5 | 1953 | 6 |
| 1959 | 13 | 1952 | 7 |
| 1958 | 6 | 1951 | 4 |
| 1957 | 1 | 1950 | 1 |
| 1956 | 4 | 1948 | 1 |

*Grade Placement*

| | | | |
|---|---|---|---|
| Kg | 1 | 9 | 3 |
| 2 | 2 | 10 | 3 |
| 3 | 3 | 11 | 1 |
| 4 | 3 | CSB | 16 |
| 5 | 1 | Deaf | 7 |
| 6 | 2 | Ungraded | 9 |
| 7 | 1 | DCHM | 1 |
| 8 | 3 | Not reported | 2 |

*Visual Acuity*

| | | | |
|---|---|---|---|
| No vision | 6 | 20/200 | 10 |
| LP | 14 | Partial | 2 |
| Some | 18 | Not reported | 6 |
| Blind | 2 | | |

*Hearing Loss*

| | |
|---|---|
| Moderate | 14 |
| Severe | 25 |
| Degree not reported | 19 |

*Cause of Blindness*

| | | | |
|---|---|---|---|
| Cataracts | 11 | Aphakia | 4 |
| Rubella | 8 | Myopia | 2 |
| RLF | 7 | Various | 9 |
| Congenital | 6 | Not reported | 5 |
| Optic atrophy | 6 | | |

*School Placement*

| | | | |
|---|---|---|---|
| Local schools | 38 | DCHM | 1 |
| CSB | 16 | Not reported | 2 |
| CSD | 1 | | |

## Table 6B

## 58 Deaf-Blind Children in School

| *Handicap* | *Educable* | *Trainable* | *Uneducable* | *Degree Not Reported* | *Total* |
|---|---|---|---|---|---|
| Mental | 13 | 9 | 5 | 5 | 32 |
| | Mild | Moderate | Severe | | |
| Hearing | -- | 14 | 25 | 19 | 58 |
| Communication | 1 | 3 | 18 | 2 | 24 |
| Speech | 1 | -- | 19 | 5 | 25 |
| Cerebral palsy | -- | 3 | 1 | 1 | 5 |
| Orthopedic | -- | -- | 1 | -- | 1 |
| Epilepsy | -- | -- | -- | 2 | 2 |
| Emotional | 2 | 2 | 5 | 2 | 11 |
| Various | -- | -- | -- | 3 | 3 |
| Total | 17 | 31 | 74 | 39 | 161 |
| Percent | 10.5 | 19.3 | 46.0 | 24.2 | |

*Number of Handicaps in Addition to Blindness*

| Handicaps | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| *N* of children | 16 | 12 | 8 | 15 | 6 | - | 1 |

| Average number of handicaps per child (including blindness and deafness): | 3.8 |
|---|---|

*Recommendation for Future Placement*

| | |
|---|---|
| Remain | 38 |
| Should not remain | 3 |
| Not reported | 17 |

## Table 6C

## County Distribution

*58 Deaf-Blind in School*

| | |
|---|---|
| CSB | 16 |
| CSD (North) | 1 |
| Alameda | 3 |
| Contra Costa | 3 |
| Kern | 1 |
| Los Angeles | 14 |
| Mendocino | 1 |
| Orange | 2 |
| Riverside | 2 |
| Sacramento | 2 |
| San Bernardino | 3 |
| San Diego | 3 |
| San Francisco | 1 |
| San Joaquin | 2 |
| Santa Clara | 1 |
| Solano | 1 |
| Tulare | 1 |
| Ventura | 1 |

## Table 7A

## 18 Deaf-Blind Children in State Hospital Schools

*Year of Birth*

| | *N* | | *N* |
|---|---|---|---|
| 1962 | 1 | 1956 | 3 |
| 1960 | 1 | 1955 | 4 |
| 1959 | 1 | 1953 | 1 |
| 1958 | 3 | 1950 | 1 |
| 1957 | 2 | Not reported | 1 |

*Grade Placement*

| | |
|---|---|
| Ungraded | 18 |

*Visual Acuity*

| | |
|---|---|
| No vision | 5 |
| LP | 2 |
| Some | 1 |
| Blind | 4 |
| Not reported | 6 |

*Hearing Loss*

| | |
|---|---|
| Moderate | 7 |
| Severe | 9 |
| Not reported | 2 |

*Cause of Blindness*

| | |
|---|---|
| Cataracts | 6 |
| Rubella | 3 |
| RLF | 2 |
| Pigmentary degeneration | 2 |
| Various | 5 |

## Table 7B

## 18 Deaf-Blind Children in State Hospital Schools

| *Handicap* | *Educable* | *Trainable* | *Uneducable* | *Degree Not Reported* | *Total* |
|---|---|---|---|---|---|
| Mental | 1 | 12 | -- | 5 | 18 |
| | Mild | Moderate | Severe | | |
| Hearing | -- | 7 | 9 | 2 | 18 |
| Communication | -- | 2 | 14 | -- | 16 |
| Speech | -- | -- | 16 | -- | 16 |
| Cerebral palsy | -- | 1 | -- | -- | 1 |
| Orthopedic | -- | 1 | -- | -- | 1 |
| Emotional | -- | 2 | 3 | -- | 5 |
| Heart | -- | -- | -- | 1 | 1 |
| Total | 1 | 25 | 42 | 8 | 76 |

*Number of Handicaps in Addition to Blindness*

| Handicaps | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| *N* of children | - | 2 | - | 9 | 6 | 1 | - |

Average number of handicaps per child (including blindness): 4.2

## Table 8A

## 35 Deaf-Blind Children (School Age)
## Not in School

*Year of Birth*

|  | *N* |  | *N* |
|---|---|---|---|
| 1960 | 4 | 1953 | 2 |
| 1959 | 5 | 1952 | 6 |
| 1958 | 3 | 1951 | 1 |
| 1957 | 3 | 1950 | 1 |
| 1956 | 2 | 1949 | 1 |
| 1955 | 3 | 1948 | 1 |
| 1954 | 2 | 1947 | 1 |

*Visual Acuity*

| | |
|---|---|
| No vision | 7 |
| LP | 4 |
| Some | 3 |
| Blind | 11 |
| Not reported | 10 |

*Hearing Loss*

| | |
|---|---|
| Mild | -- |
| Moderate | -- |
| Severe | 22 |
| Not reported | 13 |

*Cause of Blindness*

| | |
|---|---|
| Cataract | 6 |
| Rubella | 4 |
| Brain damage | 3 |
| Microcephalos | 3 |
| RLF | 2 |
| Various | 4 |
| Not reported | 13 |

*Placement*

| | |
|---|---|
| Home | 24 |
| Left school | 6 |
| DCHM | 1 |
| Not reported | 4 |

## Table 8B

## 35 Deaf-Blind Children (School Age) Not in School

| *Handicap* | *Educable* | *Trainable* | *Uneducable* | *Degree Not Reported* | *Total* |
|---|---|---|---|---|---|
| Mental | 3 | 5 | 10 | 3 | 21 |
| | Mild | Moderate | Severe | | |
| Hearing | -- | -- | 22 | 13 | 35 |
| Communication | -- | 1 | 13 | 4 | 18 |
| Speech | -- | 2 | 14 | 2 | 18 |
| Cerebral palsy | -- | 1 | 6 | 2 | 9 |
| Orthopedic | 1 | 4 | 7 | 3 | 15 |
| Epilepsy | -- | -- | -- | -- | -- |
| Emotional | -- | -- | 1 | 4 | 5 |
| Heart | -- | -- | -- | 2 | 2 |
| Neurological | -- | -- | -- | -- | -- |
| Other | -- | -- | -- | 1 | 1 |
| Total | 4 | 13 | 73 | 34 | 124 |
| Percent | 3.2 | 10.5 | 58.9 | 27.4 | |

*Number of Handicaps in Addition to Blindness*

| Handicap | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| *N* of children | 12 | 4 | 1 | - | 7 | 11 | - |

Average number of handicaps per child (including blindness): 4.5

## Table 8C

## County Distribution

| *35 Deaf-Blind Children (School Age) Not in School* | |
|---|---|
| Alameda | 1 |
| Butte | 1 |
| Contra Costa | 1 |
| Los Angeles | 5 |
| Madera | 5 |
| Orange | 1 |
| Placer | 3 |
| Riverside | 1 |
| San Bernardino | 1 |
| San Diego | 3 |
| San Francisco | 1 |
| San Joaquin | 1 |
| San Luis Obispo | 1 |
| San Mateo | 3 |
| Sonoma | 2 |
| Not reported | 5 |

## Table 9A

## 129 Deaf-Blind Children of Preschool Age

*Year of Birth*

|  | *N* |  | *N* |
|---|---|---|---|
| 1967 | 2 | 1963 | 12 |
| 1966 | 24 | 1962 | 20 |
| 1965 | 38 | 1961 | 2 |
| 1964 | 31 |  |  |

*Visual Acuity*

|  |  |
|---|---|
| No vision | 9 |
| LP | 22 |
| Some | 16 |
| Blind | 6 |
| 20/200 | 4 |
| Partial | 7 |
| Not reported | 65 |

*Hearing Loss*

|  |  |
|---|---|
| Mild | -- |
| Moderate | 3 |
| Severe | 45 |
| Not reported | 81 |

*Cause of Blindness*

|  |  |  |  |
|---|---|---|---|
| Rubella | 92 | RLF | 2 |
| Cataracts | 7 | Microcephalos | 2 |
| Optic atrophy | 3 | Various | 13 |
| Congenital | 3 | Not reported | 7 |

*Placement*

|  |  |
|---|---|
| Home | 78 |
| John Tracy Clinic | 19 |
| S.F. Hearing & Speech Center | 12 |
| S.F. State College | 7 |
| Preschool (nursery) | 5 |
| DCHM | 2 |
| Left school | 1 |
| Not reported | 5 |

## Table 9B

## 129 Deaf-Blind Children of Preschool Age

| *Handicap* | *Edu-cable* | *Train-able* | *Unedu-cable* | *Degree Not Reported* | *Total* |
|---|---|---|---|---|---|
| Mental | 17 | 33 | 12 | 32 | 94 |
| | Mild | Moder-ate | Severe | | |
| Hearing | -- | 3 | 49 | 77 | 129 |
| Communication | -- | 2 | 30 | 24 | 56 |
| Speech | -- | 1 | 37 | 23 | 61 |
| Cerebral palsy | 1 | 1 | 2 | 14 | 18 |
| Orthopedic | 1 | 1 | 1 | 11 | 14 |
| Epilepsy | -- | -- | 2 | 6 | 8 |
| Emotional | -- | 2 | 6 | 13 | 21 |
| Heart | -- | -- | -- | 32 | 32 |
| Neurological | -- | -- | -- | 4 | 4 |
| Other | -- | -- | -- | 5 | 5 |
| Total | 19 | 43 | 139 | 241 | 442 |
| Percent | 4.3 | 9.7 | 31.5 | 54.5 | |

*Number of Handicaps in Addition to Blindness*

| Handicaps | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| *N* of children | 17 | 25 | 20 | 36 | 16 | 14 | 1 |

Average number of handicaps per child (including blindness): 4.4

## Table 9C

## County Distribution

*129 Deaf-Blind Children of Preschool Age*

| | |
|---|---|
| Alameda | 2 |
| Butte | 1 |
| Colusa | 1 |
| Contra Costa | 3 |
| Humboldt | 1 |
| Imperial | 2 |
| Los Angeles | 51 |
| Monterey | 2 |
| Orange | 4 |
| Placer | 1 |
| Riverside | 3 |
| Sacramento | 13 |
| San Bernardino | 2 |
| San Diego | 4 |
| San Francisco | 20 |
| San Joaquin | 3 |
| Santa Clara | 5 |
| Shasta | 3 |
| Siskiyou | 1 |
| Solano | 1 |
| Sonoma | 2 |
| Tulare | 1 |
| Ventura | 3 |

## Table 10

### Comparison of Percentages of Severity of Handicaps for Seven Groups of Multihandicapped Blind Children

| | | *Severity of Handicaps* | | | |
|---|---|---|---|---|---|
| *Groups* | N | *Mild* | *Moderate* | *Severe* | *Degree Not Reported* |
| Multihandicapped blind in school | 537 | 30.5 | 24.9 | 12.7 | 31.9 |
| Multihandicapped blind in state hospital schools | 82 | 11.4 | 49.8 | 16.4 | 22.4 |
| Multihandicapped blind not in school | 189 | 7.8 | 19.2 | 19.7 | 53.3 |
| Multihandicapped blind of pre-school age | 132 | 11.7 | 16.8 | 27.6 | 43.9 |
| Deaf-blind in school | 58 | 10.5 | 19.3 | 46.0 | 24.2 |
| Deaf-blind not in school | 35 | 3.2 | 10.5 | 58.9 | 27.4 |
| Deaf-blind of pre-school age | 129 | 4.3 | 9.7 | 31.5 | 54.5 |

## Table 11

### Comparison of Average Number of Handicaps for Seven Groups of Multihandicapped Blind Children

| *Groups* | *Average Number of Handicaps Per Child* |
|---|---|
| Multihandicapped blind in school | 3.0 |
| Multihandicapped blind in state hospital schools | 3.7 |
| Multihandicapped blind not in school | 3.0 |
| Multihandicapped blind of preschool age | 3.7 |
| Deaf-blind in school | 3.8 |
| Deaf-blind not in school | 4.5 |
| Deaf-blind of preschool age | 4.4 |

## Table 12

## Frequency of Handicaps for 940 Multihandicapped Blind Children

| Handicaps | 537 in School | 82 State Hosp. Schools | 189 Not in School | 132 Pre-school | No. of Children | % of 940 Total |
|---|---|---|---|---|---|---|
| Mental | 350 | 82 | 130 | 102 | 664 | 70.6 |
| Hearing | 20 | -- | 6 | 3 | 29 | 3.1 |
| Communication | 73 | 38 | 28 | 65 | 204 | 21.7 |
| Speech | 143 | 39 | 34 | 49 | 265 | 28.2 |
| Cerebral palsy | 76 | 7 | 36 | 24 | 143 | 15.2 |
| Orthopedic | 48 | 7 | 19 | 18 | 92 | 9.8 |
| Epilepsy | 33 | 6 | 11 | 12 | 62 | 6.6 |
| Emotional | 214 | 20 | 84 | 53 | 371 | 39.5 |
| Heart | 7 | -- | 2 | 9 | 18 | 1.9 |
| Deprivation | 68 | 1 | 5 | -- | 74 | 7.8 |
| Neurological | 9 | 10 | 21 | 2 | 42 | 4.4 |
| Various | 45 | 9 | 10 | 14 | 78 | 8.3 |
| Total | 1,086 | 219 | 386 | 351 | 2,042 | |

## Table 13

## Frequency of Handicaps for 240 Deaf-Blind Children

| *Handicaps* | *58 in School* | *18 State Hosp. Schools* | *35 Not in School* | *129 Pre-school* | *No. of Children* | *% of 240 Total* |
|---|---|---|---|---|---|---|
| Mental | 32 | 18 | 21 | 94 | 165 | 68.8 |
| Hearing | 58 | 18 | 35 | 129 | 240 | 100.0 |
| Communication | 24 | 16 | 18 | 56 | 114 | 47.5 |
| Speech | 25 | 16 | 18 | 61 | 120 | 50.0 |
| Cerebral palsy | 5 | 1 | 9 | 18 | 33 | 13.8 |
| Orthopedic | 1 | 1 | 15 | 14 | 31 | 12.9 |
| Epilepsy | 2 | -- | -- | 8 | 10 | 4.2 |
| Emotional | 11 | 5 | 5 | 21 | 42 | 17.5 |
| Heart | -- | 1 | 2 | 32 | 35 | 14.6 |
| Neurological | -- | -- | -- | 4 | 4 | 1.7 |
| Various | 3 | -- | 1 | 5 | 9 | 3.8 |
| Total | 161 | 76 | 124 | 442 | 843 | |

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EC = exceptional children
IJEB = International Journal for the Education of the Blind
OB = The New Outlook for the Blind

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QUESTIONNAIRE A

## MULTIHANDICAPPED BLIND CHILDREN *IN SCHOOL*

For the purpose of the study, multihandicapped blind children are defined as visually handicapped children with other *marked* handicaps who for reason of their combination of handicaps cannot or should not be admitted to, and cannot profit satisfactorily from, classes provided for blind, mentally retarded, or other handicapped children. Please indicate in the relevant columns for each child whether the handicapping condition is A (mild), B (moderate), C (severe). If this is not known, insert only a checkmark. In the MR column indicate whether the child is considered E (educable), T (trainable), or U (uneducable).

| Name | Date of Birth | Special Class or Grade | Visual Handicap | | Other Handicaps (leave blank if not applicable) | | | | | | | | | Will Remain | Should Not Remain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Acuity | Cause | Mental Retard. | Hearing | Communication | Speech | Cer. Palsy | Orthopedic | Epilepsy | Emotional | Other | | |
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QUESTIONNAIRE B

## MULTIHANDICAPPED BLIND CHILDREN *NOT IN SCHOOLS*

For the purposes of the study, multihandicapped blind children are defined as visually handicapped children with other *marked* handicaps who for reason of their combination of handicaps cannot or should not be admitted to, and cannot profit satisfactorily from, classes provided for blind, mentally retarded, or other handicapped children. Please indicate in the relevant columns for each child whether the handicapping condition is A (mild), B (moderate), or C (severe). If this is not known, insert only a checkmark. In the MR column use E (educable), T (trainable), or U (uneducable), if this is known. In the last four columns, please enter any information that is known to you about the status and location of the child.

| Name | Date of Birth | Visual Handicap | | Other Handicaps (leave blank if not applicable) | | | | | | | | | Status | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Acuity | Cause | MR | Hearing | Communication | Speech | Orthopedic | Epilepsy | Emot. | Other | Left School | Not Admitted | At Home | Elsewhere (give detail) |
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# MODERN TRENDS IN MOBILITY*

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May I first say how very pleased I am to be here today to talk to you about modern trends in mobility.

I took part last weekend in a conference at Leicester held by your sister organization, the Southern Regional Association, when the whole topic of mobility was dealt with exclusively. At this meeting there was certainly unanimous agreement on the point that we are now in an era of the scientific approach to the problem of mobility, and I would therefore like to start my address by defining a little more precisely what is meant by this term: quite simply it is to look at the problem objectively and without prejudice of any kind.

It is a unified approach, that is, the problem of mobility is looked at in the same way as that relating to other systems such as aircraft, weapons, or traffic: we analyze requirements, look at available and projected resources, and arrive at suitable matches between these resources, requirements and the user population.

It is a wholistic approach inasmuch as mobility as a skill cannot be divorced from other aspects of the user of the skill and this means that research and welfare considerations are bound to overlap.

Finally, it is an independent approach so far as the kind of research projects with which my colleagues and myself are concerned--that is to say our recommendations by themselves do not carry policy implications and we must remain independent of, although in close cooperation with, those who make such policy.

## Research Project—The Two Aims

I am a member of the external staff of the Medical Research Council and the project with which I am personally associated has, as its short-term aim, to collect and make available existing "know-how" which can bring the level of mobility of the average blind population to that of the best existing examples here and now. The long-term aim is to provide the knowledge to enable the blind to be as mobile as the sighted, and here I would like to take the opportunity to clarify that: stating as

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*This paper was presented by Dr. Leonard to a General Council Meeting of the North Regional Association for the Blind on November 24, 1966. It is reprinted by kind permission of the author and the Association.*

as our ultimate objective a degree of mobility which compares favorably with that of the sighted does not mean that every blind person will or should be expected to walk about independently all the time. What it does mean, which is something quite different but equally important, is that we wish to provide the know-how and facilities which should enable blind people to be independent when they want to so that they know that they could solve a particular problem by themselves.

## Specifying the Problem and Examining Existing Solutions

At a St. Dunstan's conference on sensory devices which I attended earlier this year the very profound statement that "there seem to be an awful lot of solutions for which there do not appear to be any problems" was made at the close of the meeting by John Dupres, a blind engineer-cum-psychologist who is in charge of one of the big research projects in the United States. This provides food for very solemn thought for us all, but especially to people like myself whose profession and reputation is, of course, engaged in finding solutions.

The first step in our project was to specify the problems and how to set about them. In order to assess the properties of the user population, the Ministry of Health agreed that the Central Office of Information should carry out a survey of the blind population of England and Wales: this has now been completed; it deals specifically with the problems of reading and mobility.

Next we had to know something about the basic requirements for mobility as such. A table outlining the form of systems analysis appeared in the September issue of the Southern Regional *Review* in my paper dealing with the subject of a unified approach to the mobility of blind people. Requirements are placed down one side, with resources along the top of the table; which requirement is met and to what extent is then filled in. My talk this afternoon will to some extent follow this pattern.

Then we had to know something about the existing and already projected resources; this meant that we had to undertake a study of the existing systems--that is, people going about with no aids, short and long canes, guide dogs, electronic aids, and so forth.

Fourth, we had to ensure that the existing systems and knowledge were fully exploited for the benefit of the general blind population, entailing recommendations to organizations, talks, and publications. Thus we can now specify a little more clearly the general problems and can also say rather more about the remaining problem areas.

## The Survey

I would like to spend a little time now on one aspect of the survey carried out by the Central Office of Information and give you a small sample of the data available from a professionally carried out survey of this kind. A total of some 1,500 blind people in England and Wales was sampled and of this number approximately 1,000 were between the ages of 16 and 64 and 500 were between the ages of 65 and 79. Data are not yet available in respect to this older category, but the sampling ratio of 1 in 30 for the younger population is quite a good proportion, and you may be interested in some of the figures presented at the recent meeting of the British Association at Nottingham. Of this younger population, 63 percent went out on foot unguided and about one half did less than a period of three hours in this respect during the week preceding their interview.

During the survey some simple questions were asked about degrees of vision because this could not be obtained adequately from Forms B.D.8--another solemn thought--and a rough breakdown of those who could not see windows, that is, with perception of light or less--revealed that 76 percent of the men within the age group 16 to 49 went out unguided, 60 being the percentage for women.

Thus we get a picture showing first, that right through there is an obvious effect of vision--the higher the degree of vision the more people went out. Second the effect of age--the older people become the less they go out unguided. Third, and most important, there is a very interesting effect so far as sex is concerned: it was found that women go out unguided much less than men.

Taking the whole of the younger population again--that is, those between 16 and 64 years of age--63 percent said that they would be prepared to go on a half-mile unfamiliar trip. This now brings us to the question of the extent to which new ground is actually being covered, and 77 percent within the group said that they had not done so at all during the previous three months.

Another very straightforward question involved measurement of the distance between the tip of the elbow and the ground. These readings produce statistical distribution and this varies, of course, but the vast majority were between 40 and 42 inches. A further inquiry relating to stick length revealed that by far the largest number of sticks in use were 36 inches long, only 2 percent being 40 inches long.

To the extent that the minimum length of the long cane (about which I will say more later) is from elbow to ground, it is clear that for most people the existing cane is several inches too short and it is good to know that, quite apart from the long cane itself, the RNIB have made the 40-inch collapsible one more widely available.

## Information Processing for Blind Travel

Now I want to turn to a specification of the general problem of mobility. In the first place, travel requires information concerning the direction which has to be followed; second, the existence of obstacles along the travel path and the alternative routes; and third, the nature of the terrain--that is, the unevenness, texture, curvature, and so forth of the ground underfoot. All this has to be assimilated before we take up a given direction, encounter and negotiate an obstacle, or place our foot to make the next step (this is very important because, so far as the majority of blind travel in this country is concerned at the moment, there is a very real sense in which you can say that every time a blind person puts a foot forward he steps into uncertainty.

All this information has to be taken in continuously and with little conscious effort. Vision enables one to cope with these requirements, providing the mind continuously with highly redundant (that is, superfluous) information which is processed with little awareness but can be attended to with a great deal of awareness and concentration the moment it is required--the moment anything out of the ordinary happens. But, as far as blind mobility is concerned, it is this function of vision in combination with the mind which has to be taken over by the remaining senses, primarily touch and hearing, neither of which are particularly well suited to meet these functions. That is the difficulty, and it is for this reason that all existing known forms of blind travel require a considerable amount of conscious effort is they are to be carried out efficiently--whether without any aid, with a cane, or even with a dog.

In comparing existing methods, assessing projected methods, and developing new methods, we have to consider not merely the efficiency with which these deal with the specific problems they set out to solve but also the ease of handling and extent to which the information these things provide can be monitored at low levels of awareness but attended to smartly and in detail when required.

## Sense Training

So now let us look at some of these resources. Of the existing ones--that is, the importance of hearing and vision, residual vision, touch, and the rest--you will all be fully aware, and I will therefore deal more specifically with the problems of sensory training and the researches being carried out into this in this country, the United States, and at Innsbruck in Austria which is one of the homes of this kind of work.

The problem here is that we know that a large number of blind people can make extremely good use of hearing; also, from experiments carried out over the last twenty years, we know that the ability to use hearing for blind travel can be taught and can be acquired by sighted people. It can also be acquired by newly-blinded people, but what has not yet been developed is an adequate training method. To clarify any misunderstanding here, there are certainly lots of people all over the world, including this country, who are teaching blind people how to make use of hearing, but these are individual efforts, difficult to hand on from one instructor to another, and there is not yet a formalized basis.

Professor Kohler of Innsbruck was largely responsible for some of the early work in this direction, along with Professor Beuule, now at Nottingham, who was working with St. Dunstan's in the fifties. They both independently developed a training aid in the form of a clicker. It is important here to stress that this was not intended to be utilized other than as a training aid.

This works on the principle of providing a regular series of clicks and blind (or sighted people blindfold) can be trained to appreciate the echoes as they are reflected from solid and other surfaces; the device can then gradually be faded out so that people can appreciate the echoes generated by themselves, for example, their footsteps. It is thus purely and simply a training device for the enhancement of ordinary hearing, but what is revealing is that, although this knowledge has existed for over twenty years in this country and the United States, so far we have not been able to make systematic use of it: this is one of the knottiest problems still with us.

## Long Cane

And so we come to the long cane which is now here for good in this country, thanks to the efforts of the RNIB and St. Dunstan's. I had hoped to demonstrate the very beautiful collapsible version which the RNIB has produced but unfortunately they are all out on field traisl.

First, I shall try to briefly establish just what the long cane means. The object is to provide a blind person with a tool that effectively extends his hand so that the area in front of his forward path can be sensed tactually. This sounds very simple and straightforward, I know, and when you address an audience not in blind welfare or research they see this as obvious and wonder why it has not been done previously. Well, there are all sorts of snags concerned with it, one being the fact that the cane is a tool required perhaps for only 5 to 10 percent of the time daily and for the remainder it is somewhat of a nuisance and has to be tucked away: for this reason efforts have been going on in the United States and here to make it collapsible. The other snag, and this is the more important, concerns the problem of training. It must be quite clearly understood that the long cane and its associated techniques have to be taught by qualified instructors for long periods of time--anything up to ten weeks. It is a continuous and expert training, a form of training that requires the incorporation of a new tool in what we call the body schema or image--it has to become as much a part of your body as the pen with which you write, the car you drive, or anything of this kind. It does require highly specialized training and a lot of it: otherwise, and without a doubt, all sorts of troubles are liable to be encountered.

The ideal position of the cane is midline of the body, with the arm well tucked in, and a sweeping movement of the ground synchronized with one's footsteps is required starting from, and purely from, the wrist and covering the ground just about one step ahead in the direction being followed. This requires a cane length that is at minimum the height I previously mentioned--that is, from the elbow to the ground. In country districts, or if walking particularly fast, you can afford to go higher--up to the bottom of the chest bone, adding about another three inches or so.

There are still quite a number of problems connected with the long cane, and I know Mr. Colligan would like to say something about these later on. Suffice it for me to mention two here: one is that we may run into quite a number of serious problems concerned with the difference between the congenital blind and those who become blind later on in life: for one thing, most of the knowledge available about the long cane technique has arisen from the work of the Veterans Association in the United States which has worked with the war-blinded only.

The second problem is a more fundamental one and relates to certain differences in regard to perception--perceptual difficulties in the congenitally blind as distinct from the adventitiously blind as they are now called. I suspect, although there is no concrete evidence of this as yet, that people who have been blind from birth have considerable difficulty in attempting to sense objects any distance away from the tips of their feet and the tips of their fingers.

This is a conceptual problem we encountered for the first time when we tried to evaluate the sonic aid, and I will now illustrate what I suspect it means in practice.

A well-trained blind cane traveler walking along the pavement, on discovering that he is not really on a straight path but heading for the curb, remains in the last position which he has reached safely and uses his long cane in order to sort out the terrain around him. Now I think it is going to emerge that there is a strong tendency for a congenitally blind person to use the tip of his foot to do this sensing and the moment he does so he has lost his last safe place and may lose his orientation (it is quite possible that one of the difficulties about any new form of aid that extends to the perceptual range of the blind person lies in this basic conceptual difficulty of sensing objects at a distance away from the direct contact of foot and fingertips).

Another problem has to do with training. The Veterans Administration at Hines set an extremely high standard: they train their people from two to three hours per day for anything up to three months, and it is therefore a very good thing that a Hines instructor is at present in charge of the training program of the RNIB at Torquay. Having said this, I must also add that the Hines training is not sacrosanct and everybody from its founder, Dick Hoover, right down to its present senior people are agreed on the fact that no one so far has found a way round it. Thus, it is a fit matter for further research and the Nuffield Foundation has very kindly made a grant to the University of Nottingham for this purpose: a form of clinical trial is at present in process in a non-residential setting in Birmingham where an American instructor is teaching some blind people, and also some sighted instructors, in order to establish whether it is possible to reduce the training first of the instructors and then of the blind persons themselves.

## Guide Dogs

I now want to mention three problem areas concerned with guide dogs. What we want to know here is the extent to which their usefulness is limited and the reasons for this being the case. Granted that this is a very good system, there are severe limitations in the kind and number of people who can avail themselves of it. The second problem, and a very interesting one (which I certainly did not realize until working very closely with the Guide Dog Association) is that one has to work quite hard to prevent the dog from getting distracted--there is a continual interchange between the blind user and the dog in order to insure that the dog stays "with it." It is very hard work, and the continuous interchange of information requires a very special relationship which could be best likened to that existing between a senior NCO and a field officer in that there has to be mutual respect and mutual responsibility: the dog has got to be able to say no from time to time within a setting of obedience, and to do this presents a large number of people with a very serious problem.

The third problem associated with the use of guide dogs relates to the current lack of facilities for the majority to have some other form of secondary mobility training; this is something which I think requires looking into so that guide dog owners are not entirely dependent on the presence of the animal.

## The Human Guide

The remaining proved aid, that of the human guide, has many problems concerned with its effectiveness: for instance, how to ask for adequate escorting and how to provide for it, how to guide over new routes, for example, for a blind person seeking directions and a sighted person giving them.

Much of this is linked up with that delicate subject, the problem of educating the blind and the sighted on how to collaborate with each other, but it does seem to me, following perusal of the literature and in talking to knowledgeable persons on this aspect, that there has been a certain amount of neglect by way of formal training in this very obvious and straightforward area of aids to blind people. We are doing a little about this in the form of map work on which I shall say more later.

## Electronic Aids

Meantime, I would like to turn to the newer innovations for blind travel--that is, electronic aids. The one I have available here is that invented by Professor Kay, sponsored by St. Dunstan's and marketed by Ultra. This is a sensory device that sends out a narrow ultrasonic beam in a pulsed fashion: you listen to the echo as it returns and the higher the pitch the further away the object, the nearer it is the lower the pitch. It does provide the only possibility, at present, for blind people to sense objects in any detail at a distance, but evaluations both here and in the United States show that this aid can only be used continuously whilst moving at a very slow pace: it can therefore best be regarded as one of a number of possible devices that can be used for environmental sensing or picking up landmarks for straight-line travel. It is not, as it stands at the moment, in any way useful to provide continuous safe information, but, as I suggested, there is a possible use for it as a navigational aid in conjunction with other aids--that is, the cane or guide dog.

Professor Kay's work is continuing on the other side of the world in New Zealand in connection with other devices of this kind and I for one wish it every success. One of the beauties of doing research, incidentally, is that every morning you go to your desk in the hope of a little airmail letter from someone somewhere to say "Boy, we've licked it": I can tell you sincerely that I would be only too delighted to have such a letter even though it might put me out of this job.

Another approach at the moment, which is viable and rather a different idea, is that of a rather wide-angled, as distinct from the very narrow-beam, device; you carry this on your chest and it gives information as to whether objects are 20, 12, 8, or 6 feet ahead of your travel path. It does so by producing one of four very simple signals, easily distinguished from each other so that there is no grading, differentiation, or detail, just a simple indication whether the path ahead is clear. This was designed by Lindsey Russell of the United States, but even this turns out to be too difficult to listen to for any length of time.

## The "Radio Compass"

All those concerned with blind mobility, either with the blind themselves or on the welfare and rehabilitation side, will know that to maintain a straight path in the absence of adequate cues is a major difficulty, and the next device I have here is a transistor radio turned into a radio-compass and devised by Jim Swaile of Canada.

By reason of its ferrite core aerial, an ordinary transistor portable is highly directional, and Jim Swaile put this to use with a little modification on it to get a simple signal: the receiver is turned to obtain the lowest pulse rate, and as long as you hear this a straight course is maintained. This device is at the moment being used experimentally in a sort of harness to mount it on the chest, since it has been discovered that it is somewhat difficult for blind people to relate the position of the hand to the body.

One of the main reasons for the need of a form of simple compass device is concerned with a travel problem. When the directions are to walk on the left side of a road, to stop on the down-curb, cross over to the next up-curb, and turn left for your true path, it could happen very easily with a wide junction that the blind person veered to the right, crossed diagonally, and made his left turn there: he would have done quite the right thing in the wrong place and continue happily (or unhappily) in the same direction as before but on the opposite side of the street. I have seen this occur quite frequently and not only with cane travelers but also with a guide dog.

## Maps

And now I come to the question of maps, with which I have been associated for about a year. What I am going to show you is not a single solution of the map problem in blind travel but a range of solutions to meet different requirements--a single ideal solution does not exist, but what does exist are about five solutions, each of which is far from ideal. First we distinguish between district and route maps, maps that have to be kept at home and those used tactually and those auditorally, and finally between the man-produced article as the RNIB map of London (with its directory attached) and the kind executed on a do-it-yourself basis for individuals in a particular town.

It is about the do-it-yourself approach which I want to talk to you because this is the aspect we have been concentrating on lately.

*Town Plans.* It is fairly easy to make a raised town plan by taking an existing printed plan and putting 1/16-inch narrow adhesive tape over the main streets. If you can find a plan with a scale of something like seven inches to one mile, you should be able to provide the blind person with quite a reasonable outline of the main pattern of streets, and of their relationship to each other: you would not use this map for any detailed work and you would not expect to carry it round with you.

*"Campus"-Type Plans.* This refers to the sort of situation found in schools, institutes, and universities; there are large open spaces, clusters of buildings, and a network of streets and paths: you want the blind user to be able to "scan" the map in the way a sighted person would, and you want him to be able to find his way between the various buildings.

When we scan a map visually, we effectively pick out some parts and disregard all others. We can do this either because the relevant features have already been made visually dominant--for example, by making major roads a different color from the rest--or because we are able to attend selectively to features of our own choosing--for example, when we follow one bus route to the exclusion of others. For a tactually-presented map, this means providing high contrast between two or three forms of tactual codes--a process dealt with well in the RNIB geographical maps for schools. We have taken a very large photostat of a map of our Nottingham campus. Streets are laid out with "Scotch" double adhesive tape, because this has got a pleasantly rough backing and because one can cut it down to various widths, to about 1/4 inch in fact. Buildings are represented by cutting out their shape from a very smooth sheet of plastic just a little less thick than the tape marking the streets. We therefore have three easily discriminable textures; the background of the map denotes open spaces, the tape streets, and the plastic buildings.

The second problem, that of finding your way between buildings, is solved by the use of a "polar coordinate grid system" which enables one to identify any place on the map by a four-digit grid reference: this is the system used in at least one commercially available town plan. You attach something like a measuring tape to the center of the top edge of your map so that it can be moved freely around your fixture; this tape acts as a moving radius for a circle which you place along the edges of your map: both the tape and the fixed circular scale are marked off in braille, two digits to each position. By these means you can build up a dictionary of four-digit grid references for any part of your plan.

Three blind students at Nottingham are using such maps and when I asked to borrow one to show this audience, there was marked reluctance to let me have the map for three days. I assume that this is one sign of user approval.

And now to route maps of which I illustrated a very simple form, made again chiefly by do-it-yourself methods, in last February's issue of the *New Beacon*. The point here is that, by using a material which indicates directly which side of the street you are on, there is again high tactual discrimination and a very direct form of information transmission.

Routes can be broken down into identifiable sections. The most obvious sections are the end of street blocks. At each end of blocks there are basically only five actions you can take; carry straight on, turn left or right before crossing, and turn left or right after crossing. It is possible to design a simple letter code and use this to specify the sequence of crossings and turns along a route. One puts such a sequence, in braille letters, along the outer rim of a disk which one can carry in one's hand or in one's pocket, and finally one fixes a moveable cursor, shaped like the hand of a clock, to the center of the disk. This cursor is moved on after each end of block action so that one knows where one has got to, and what one should be doing next. Because such a disk takes some of the load of one's memory it is called a memorizer: an earlier version was also described in the *New Beacon* paper last February.

For those who require to do things more elegantly, there is a tape recorder on which details of the route are dictated: this is carried round and the instructions carried out step by step. We are still carrying out experiments with this at the Guide Dog establishment at Leemington, where we are also using the disk, and the results are quite interesting.

On the matter of maps, I would like to say this. I have just started the simplest kind of work, which relates to guiding people over the routes instead of giving them maps or verbal instruction or anything in this form beforehand. Provided a certain amount of trouble is taken in sorting out a route in advance, and that the guiding is done clearly and without hesitation, this is a most effective method for the instroduction of blind people to a new route. Considering the data obtained from the survey that something like three fourths of the younger blind population had not added one iota to their existing repertoire of routes within a space of three months, perhaps you will agree that, if only for this reason, a case exists for doing this kind of work.

## Points for Consideration

Time will not allow me to deal with any further forms of basic research going on, and I shall therefore just make two final points, the first of which concerns the electronics side. I think the stage has now been reached where blind persons are in danger of being cluttered up like American tourists with cameras, transistors, and the like, and we are now thinking in terms of a simple and single unified package to serve many purposes--compass, clear path indicator, perhaps a small amount of tape recording, and maybe a very simple device for elementary reading.

The other relates to the organization of research and I must include this because of its importance. Ideally, one would have thought that research could be carried out with a single rehabilitation establishment, but experience in the United States has proved otherwise: many difficulties arise, one being that you are almost inevitably bound up with the policy decisions of the particular rehabilitation set-up involved. I therefore think that the solution I have adopted is possibly the better--being located in Nottingham and working with a number of organizations and several schools. Each have their own problems and their own policies and in each of these we can carry out a particularly relevant piece of research. For instance, in Worcester, surface presentation to be used by blind children is of particular interest and a program of map reading is being followed there which involves the teaching of these kind of tactual maps. In Leamington, on the other hand, there is more interest in direct aids to route finding and more emphasis is accordingly being given here to devices in this simpler form.

## Conclusion

In conclusion, may I say that I have found the first five years in this work most fascinating indeed and within this period have witnessed great changes taking place. I feel personally that the future will be no less exciting and promising, but it can only be so if we can continue to count on the full cooperation of all concerned. Research into the problems of mobility cannot be confined to the laboratory: it must be carried out in the outside world and with real people. It is therefore bound up with many other areas, such as welfare, and I see nothing wrong in this provided we all know what we are doing.

I referred earlier to the recent meeting at Leicester. The "message" going out from that meeting was that we have available enough knowledge and know-how to make a significant improvement of the mobility of a wide range of blind people here and now. There are the two methods of formal training, long cane and guide dog: between them they should make life easier for a good many blind people. Both require intensive training, but in both cases we can be reasonably certain that the effort put into training will have been well worthwhile.

So far, on direct aids to mobility, we have nothing to offer that compares with these existing methods: performance with the sonic aid, even after months of training, simply does not come anywhere near to that of good long cane or guide dog performance.

## Questions and Discussion

*Mr. A. Hunter* (National Federation for the Blind): As a psychologist would Dr. Leonard agree that all forms of mobility cause a certain amount of nervous tension and, if so, with which does he think a blind person would feel most relaxed--guide dog, cane, or electronic?

*Dr. Leonard:* This is an important issue and basic to our present research. It would be surprising, having regard to the tremendous degree of uncertainty involved, if all methods were not found to be stressful and experiments in fact to be carried out with blind volunteers to measure such stress, one object being to establish for which particular form of mobility training a person is likely to be best suited.

*Mr. G. A. Royle* (Lancashire C.C.): It has been suggested that home teachers of the blind should specialize more on the newly blinded by reason of the fact that they have psychological stresses and also because they can improve their mobility under concentrated attention. I doubt whether this is a fair question, but is the inculcation of techniques of improved mobility something a blind home teacher, who is primarily a social worker, could usefully deal with or is it a specialization in itself?

*Dr. Leonard:* As far a newly-blind persons are concerned, there is a strong case in evidence from the United States that the earlier mobility training is commenced the better: agreement is also practically unanimous that the basic training in mobility should be given by a sighted instructor but, on the question of who does this, to whom, and with what, I would prefer to make no comment at this stage.

*Mr. P. S. Armitage* (National Federation for the Blind): At the present stage of investigation into improved methods of electronic perception, is the time ripe for the introduction of the electronic torch to as many blind people as possible who can use this. I know that in certain quarters there is a feeling that this is not perhaps the answer but, on the other hand, it is certainly the only one available and it does seem to me that intelligent blind people can benefit from this and that, as is the case in the United States, some form of teaching groups should be inaugurated.

*Dr. Leonard:* The answer is an unqualified "No." All the evidence so far available is that the sonic aid is of no practical use to the continuing and current on-going mobility problems of blind people. Whilst in itself it could prove useful if taken in conjunction with other aids, the only two methods of mobility available at the present moment which can be taught fully and will make a considerable difference to a wide range of blind people (both so far as age and residual vision is concerned) are either the guide dog or the long cane: the time has not yet come for the electronic aid to be used on a wide scale and everything possible should be done to stop its abuse.

*Mr. F. Done* (Warrington Society): I was very interested in the aspect of instruction to other people. I have been blind for twenty years and have traveled by train and by air, in this country, and abroad, and have never experienced any difficulty in getting people to help me on any occasion when this was necessitated: in any event, I fail to see how training and information could possibly be given to the vast mass of people with whom the blind, or the deaf, come in contact.

*Dr. Leonard:* Quite obviously you are a person who can ask questions politely, kindly, and intelligently, which is 80 percent of the battle. There are, however, quite a large number of blind people who to my knowledge have not licked this problem: hence my suggestion of consideration to a two-pronged attack.

It would, of course, be easier to tackle this at the level of the blind population, which is smaller, and simply give them instruction in how to ask questions (always bearing in mind that the sighted are distinctly stupid in giving directions). This is one prong of the attack, but I see nothing wrong in the attempts made in the United States in restricted localities to have a concentrated program of public relations on TV, and the like, and this seems to be one of the possibilities which might be discussed as a project.

*Mr. F. H. Castle* (Barrow Society): In reference to the statement that the long cane is of considerable value but can only be used for 10 percent of the time, is it not possible to have a cane 40 inches long which would retract telescopically into the normal cane of 36 inches so that it could be put to much longer use?

*Dr. Leonard:* Well, quite honestly, what we would really like is an instant cane created out of a powder, picked up on a morning, and then thrown into the waste paper basket at night.

But, more seriously and as I have been saying for some time now, we are spending a tremendous amount of money on the development of electronic aids, we have a vast amount of knowledge on how to get astronauts to the moon, and here is this straightforward problem of the long cane: so let us go right ahead and make a good job of something that will be of enormous benefit to the blind population and will make a great deal of difference to them. Basically we know that, when rigid, this is a very good thing and it ought to be collapsible or retractable. But it turns out that this is not a simple problem: in order to maintain the required rigidity necessary for effective use, combined with the requisite degree of disappearability, quite some engineering problems are involved--but no more so, I would think, than the sort being encountered almost every day in space travel.

*Mr. J. C. Colligan* (RNIB): Dr. Leonard has given a most exhaustive survey, well illustrating the complexity of the problems involved and the enormous diversity of effort in the research going on to meet them and I would first like to emphasize a point made by him, which needs underlining time and time again, and this is that mobility is a skill to be learned and worked at and not part of the miraculous sixth sense with which it is so often mistakenly believed the blind are suddenly endowed.

Second, I would like to say a little principally on the question of long cane technique, not because I am not keenly interested in the many other things going on but by reason of the fact that this is a project in which the RNIB, along with St. Dunstan's, are deeply involved and concerned.

Take initially the white stick: it should be realized primarily that these are not just carried around to show a badge of blindness nor are they a support for bad legs, as a lot of people seem to think: they are an aid to better mobility. Now the long cane, evolved principally in America, certainly carries with it the learning of a completely new skill and also a new technique which is not only going to take an appreciable time to learn but will also take some appreciable time for qualified instructors to teach. Whilst I do not think we need necessarily be as rigid as in America, where instructors in the technique must have had a two-year university course in peripatology, it is for this reason that the RNIB and St. Dunstan's have set up a specific course for the training of such instructors. Our experience has already proved that it is possible to train an instructor within a lesser period than in America: by how much has not at this stage been established, but it is also very important indeed to remember that, whilst blind people are usually unable to give instruction in long-cane technique, this should not necessarily be confined entirely to the sighted.

A total of six are in course of this training under the guidance of a distinguished instructor from America and, on completion of this, three will be retained by the RNIB for work at the rehabilitation centers, one will be retained by St. Dunstan's, and two will be available on a peripatetic basis to give courses of instruction throughout the country under arrangements to be made locally. But let there be no misapprehensions here that there is a quick and easy solution in that long cane instruction can be added to the duties of home teachers or social workers: it cannot and this would be a mistaken approach. It needs a great many hours and, in fact, a great many weeks of hard slogging for one individual to teach one blind person the technique of the long cane but we believe it will ultimately be well worthwhile.

I am only too sorry that it has not been possible to show you today the prototype collapsible long cane produced by the RNIB of which I feel we in this country should be very proud. It is a very expensive piece of engineering and there are only half a dozen in existence at the moment so that it will be some time before they are available generally. Meantime, I would like to bring to your notice that it is to be recommended to the RNIB Executive Council that a long cane should only be supplied to a blind person who has taken a recognized course under qualified instruction. This is very important and a point that needs to be emphasized: it is a matter of policy that we are anxious that local authorities and voluntary agencies should know about as quickly as possible.

One final comment on the subject of mobility and in regard to the question of approach to the sighted. Dr. Leonard may be fortified by a story told by a very distinguished blind member of the House of Lords who, on being chided by a number of his colleagues that he was always chauffeur-driven and did not try and get about much by himself, determined to prove that he could do so. He set forth and, having a main road to cross, decided to ask the first person he heard with a confident footstep for help. In response to his "Excuse me, sir, I wonder if you could assist me" the retort was: "Indeed I could not, you are a damned sight better dressed than I am."

*Mr. H. Wilson* (Ministry of Labor, North-West Region): For the past five or six years quite a number of blind men in the north of England, myself included, have been using long canes made by themselves with a long piece of straight cane about 46 inches long. They would not consider using these in the city but only on the outskirts of a town or in country districts, and so would only require a retractable stick instead of these made themselves on this able principle.

*Dr. Leonard:* I do not wish any disrespect or discourtesy here but, whilst it is perfectly possible that people have used longer canes and have taught themselves how to do so, I have seen number of these instances and would be prepared to bet that this is not the kind of progress or the kind of mobility envisaged and seen under long-cane training.

The idea of the longer cane as such has been with us for quite some time, but the point is that, in order to take full advantage of the greater length with relative ease and confidence and without endangering either the blind person or other road users, considerable training is required, and I have yet to see a demonstration proving to the contrary.

*Mr. J. F. Ashworth* (Blackpool Society): I would like to ask Dr. Leonard whether he considers that the development of the sense of smell is any aid at all to the mobility of a blind person. This arises from the fact that I have had the privilege of trying to help a youngster, now about eighteen, who is also partially deaf, and taking this boy about a great deal, have noticed that he can tell the different shops, the direction of buses and trains, whether passers by are male or female, and so forth, which makes me wonder whether this olfactory organ has any bearing.

*Dr. Leonard:* Every remaining sense which can possibly be utilized must be an aid to mobility and to the general life of a blind person. When vision becomes severely impaired, you lose the major sense organ for which the human being is geared and therefore every gambit which can be used singly or in combination to make up for this loss should be exploited: it is as straightforward as that.

*Mr. R. Laurie* (National League of the Blind): I am very glad that this investigation into mobility is taking place and have been very interested in all I have heard this afternoon. Taking out of its context the reference to astronauts to the moon, this would seem to be the association so far as my colleagues and myself are concerned--only a very few persons will have this opportunity. How many of the blind will be able to go for long periods of training with the long cane; the guide dog is only of use to about 4 or 5 percent of the blind population: electronic equipment is going to be far too expensive.

In all debates about the moon, the argument is put forward as to why it should be aimed to get there when there is so much to be done on the earth. I may not share this opinion, and certainly want investigation to go on into the improvement of mobility, but feel that one thing which could be done on this earth is to have a look at our street "furniture."

This is becoming more and more confusing, more and more posts are being put up, being shifted away from the edge to nearer the middle of the pavement to accommodate cars with wing mirrors and the like, and electronic devices are certainly going to cause a big commotion.

So, whilst I approve most wholeheartedly with this investigation, I think we should not just merely think that this is enough and leave it at that. In my opinion, it cannot be developed by itself without relation to the other things happening in the streets of our towns and cities, the street "furniture," and on-the-pavement parking by cars.

*Dr. Leonard:* I heartily agree.

# FACTORS IN THE DEFINITION OF DEAFNESS AS THEY RELATE TO INCIDENCE AND PREVALENCE*

**Jerome D. Schein**

All of you here are aware of the problem that we have in defining deafness. Many of you are intimately acquainted with the reasons for this problem. The very fact that we are holding a Conference such as this obviates the necessity for exhorting you as to the desirability--in fact, the necessity--for having more adequate statistics on deafness. And also, because you are quite familiar with the problems we face, I thought it would save a great deal of tedium if, rather than reciting all of the definitions of deafness which have sprung up over the years, you were presented with a sampling of these which you will find in the attached appendix.

As you know, estimates of the prevalence of deafness in the United States, corrected for the current population, vary anywhere from approximately 90,000 to 16 million. Some of the variance in these estimates could be accounted for by the methods used in gathering data, but such considerations are not within the scope of this paper. The more apparent difficulty, the real heart of the matter, is the question of what any particular investigator, any reporter of figures, is referring to when he recounts the number of "deaf" people in a particular area.

Can we at the outset identify the basis for the difficulty in defining deafness? A review of some of the many ways in which it has been construed provides evidence that the problem in defining deafness arises from the various perspectives from which it has been viewed. Deafness is the concern of many disciplines--audiology, demography, education, medicine, psychology, rehabilitation--and each tends to introduce somewhat differing factors in delimiting this condition.

In considering the factors which have entered into the definitions of deafness, let us begin with something about which they agree: Deafness is not a disease, it is a functional disorder. Implicit or explicit recognition of deafness as an impairment of the hearing sense will be found in almost all definitions of this term. It is true that the *International Statistical Classification of Diseases, Injuries and Causes of Death* lists deafness under the heading "Diseases of the Ear

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and Mastoid Process," but no one would seriously doubt that the nosologists responsible for this useful work recognize that deafness is a consequence of disease, injury or genetic fault rather than being an illness in itself. On this one point, then, there is general agreement.

Let us look at the first factor, *chronicity*. Must the loss of hearing be permanent to be included under the term deafness? Early definitions often implied an affirmative answer to this question. However, we cannot be certain on this point as we scan the current literature. We encounter "temporary deafness," "temporary threshold shift," and other indications that the reference is to a transient loss of function. Furthermore, the advent of electronic hearing aids and advances in surgical correction have introduced an entirely new perspective with regard to this question.

The apparent agreement on deafness as a disorder of function deprives us in resolving questions of classification of the use of medicine's supreme court, pathology. The isolation of a particular organism residing within the host will not permit us, as in the diagnosis of tuberculosis, for example, to classify a particular case.

The *cause* of the disorder per se is not a consideration in labeling a person "deaf." It is true that for some purposes the etiology of deafness is of great concern, but current practice seems satisfactory in this regard. Thus, most studies which confine themselves to the investigation of deafness in conjunction with a particular etiology are careful to note this fact, so that we have studies of the "meningitic deaf," "rubella deaf," etc. It would seem safe to conclude, then, that there is no serious current intent to generally restrict the definition of deafness etiologically and, in this sense, I include any attempts to define it as a purely heritable condition.

Turning to a third factor, *locus*, various modifiers have also been added to indicate the probable site of the auditory dysfunction. A sampling of such terms will serve as a reminder of this point: Sensorineural, conductive, mixed, perceptive, central, cortical. Again it would appear that those who apply adjectives in this way usually do not intend to restrict deafness to a dysfunction occurring at a single locus.

Of unquestioned concern for most of the disciplines is the *age at which deafness occurred*. To the educator, it matters greatly whether the child has lost his hearing prior or subsequent to the development of speech. Psychologically, the age of impairment must also be considered in any theoretical formulation about the loss of hearing. But whether or not this variable should be considered in defining deafness is another question. As you know, there have been recommendations that we speak of deafness without regard for the time at which it occurs, specifying this aspect by the addition of suitable adjectives. A parallel suggestion has been that we use the term "deaf" for cases which are congenital or occur prelingually and "deafened" for hearing losses which are acquired postlingually.

Particularly in the foreign literature, we still encounter the term "deaf-mute." "Deaf and dumb" has receded almost completely from the professional literature in this country. But whether or not these terms are used, *speech ability* is frequently considered in defining deafness. What is more, the deaf themselves tend to distinguish between those with like degrees of impairment on the basis of whether or not they speak or use manual communication (the former being referred to as "semi-mute"). Of course, this particular factor cannot be completely separated from the one just previously mentioned, age of onset. Just as advances in surgical techniques and hearing aid technology may affect the way in which we currently define deafness, advances in the education of the deaf should also be taken into account. The inability to speak is the object of great concern to all educators of the deaf, and their success in overcoming this particular defect is manifest. The preservation of speech is certainly a realizable goal for those who lose their hearing postlingually.

An interesting characteristic, very seldom considered, is *earedness*. What I am referring to here is the fact that we have two ears, a fact that is occasionally overlooked in some surveys of hearing impairment. Total loss of function in one ear with the other remaining intact still permits near-normal hearing for most everyday purposes. The loss in a sound field under such a condition does not exceed 15 decibels. It is necessary, then, to be prepared for added distinctions, such as "deaf in one ear with the other normal" or "with the other having some degree of hearing loss."

It has been possible to define blindness as a given loss of visual acuity *with all possible correction*. Can we do the same with deafness? Eyeglasses, including the frame, are relatively inexpensive. They are, therefore, within the economic capability of most people. A hearing aid, on the other hand, is expensive, the more so if binaural hearing aids are required. Economically, then, hearing aids are not as readily available as glasses, nor do glasses require much upkeep. Furthermore, no presently available hearing aid can completely compensate for a hearing loss as eyeglasses correct for lenticular defects. These facts may require some consideration in a definition of deafness which recognizes our present capability for electronic amplification.

Finally, we reach *degree of loss*. All definitions relate deafness to a loss of hearing ability. But how much of a loss? Hearing impairment occurs over a long continuum. The fixing of any single point beyond which one is "deaf" is obviously an arbitrary matter and, as with many arbitrary decisions, uniform agreement is lacking as to the degree of loss necessary to warrant this appellation. The lower limit has been set by different users of the term from 15 to 82 decibels--a substantial range within which to choose. Nor will the matter rest when a point on the audiometer for pure tone threshold is selected.

Deafness principally handicaps communication. At the least, it interferes with the deaf individual's perception of oral communication in his surround. It will frequently, though not necessarily, impair his ability to orally intercede with those around him. Audiologists, recognizing that the correlation of pure tone and speech reception thresholds is not unity, have suggested that the diagnosis of deafness is not complete until speech reception testing has been done. To say more than that about the technical and theoretical decisions yet to be resolved in audiology would be inapropos here. However, we must bear in mind such technological considerations, because it is on the issue of the degree of loss to be selected as the dividing point on the auditory continuum that we have the widest disagreement.

Harry Best,[1] in his monumental review of data on the deaf in the United States, issued what appears to be a sensible dictum. He said, "The term 'deaf' should be applied only to or reserved only for persons whose hearing is entirely or practically wanting (whatever the age at which it is lost), just as the term 'blind' is applied only to persons whose sight is entirely or practically entirely gone." Such usage should appeal to those who work in or have charge of schools and classes for the deaf. Note that common parlance, represented by a standard dictionary, denotes that students in such schools and classes may have only mild losses, be hard of hearing, which is surely not the case, or at least I am certain that the educators in charge of such schools would strongly argue that it was not true of their students.

Some of the confusion which is engendered by this term could then be dissolved by accepting Best's restrictions, nor would they present difficulties to most of the professions dealing with deaf persons. An apparent exception might be the demographer. How is the person conducting a morbidity survey to assure himself that he can obtain reliable data on total loss of hearing without direct audiometric measurement? Are enough persons capable of correctly assessing their own degree of impairment? Fortunately, on this point, we have some empirical evidence.

An investigator in Indiana, Baughn,[2] asked 8,000 employees of an industrial concern, "How well do you think you hear?"

[1] *See Appendix B-1, item 2 C.*

[2] *William L. Baughn, "How Well Do You Think You Hear?" In* Proceedings of Thirteenth International Congress on Occupational Health. *New York: The Congress, 1961, pp. 667-72.*

The original alternatives offered were "good," "fair," or "poor," but the respondents themselves added a fourth response category, "deaf."

The answers he obtained to this question were correlated to audiometric hearing levels (averaged over 500, 1,000 and 2,000 c.p.s.). He found highly satisfactory relations between the subjects' estimates and their pure tone thresholds. The minimum degree of overlap between the good, fair, poor and deaf groups is quite startling. Ignoring some of the details of this excellent study, one can concentrate on the principal finding, for our purposes here, that the layman appears able to provide reasonably accurate estimates of his hearing level.

Additional confirmation of this finding comes from studies at Gallaudet College of a scale of hearing ability developed for the National Health Survey.[1] The scale consists of five statements to which the respondent answers "yes" or "no." The first statement reads, "I can hear loud noises." The fifth reads, "I can usually hear and understand most of the things a person says to me without seeing his face and lips."

These statements were first tested to see if they formed a Guttman-type scale. In this case perfect Guttman-type scaling would occur if once a respondent answered "no," all of his subsequent answers were "no." We found that 91.6 percent of the first group of 216 subjects gave Guttman-type scaled responses. Cross-validation with a second group of 171 cases yielded 91.8 percent scale responses. As you know, such consistency is unusual in psychological data.

What do these scale responses mean audiometrically? Correlations of scale scores to pure tone averages, speech reception thresholds, and speech discrimination scores for phonetically balanced words were calculated. The correlation to pure tone average was 0.74 to speech reception threshold 0.67, and to speech discrimination 0.55. Again, we are led to the conclusion that, properly questioned, people are able to provide estimates of their hearing level which agree quite well with audiometric measures.

While we may be satisfied that it is possible to obtain some estimates of hearing levels from self-reports by the adult population, we cannot for long ignore a difficulty with Best's suggestion. I refer to the attenuating phrase, "practically entirely" absent sense of hearing. How much might "practically entirely" be in measurable terms? Consider, also, a similar qualification in the familiar definition established by the

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[1] *Stanley K. Bigman, then at Gallaudet College and now at Division of Occupational Health, Public Health Service, was the originator of this scale.*

Conference of Executives of the American Schools for the Deaf: "those in whom the sense of hearing is nonfunctional for the ordinary purpose of life." As Barker *et al.*[1] point out, "Since sensitivity to sound is continuous from superior auditory acuity to loss of hearing, it is difficult, and often impossible, to specify the point at which functional hearing for the ordinary purposes of life shade into nonfunctional hearing" (p. 191).

What then is the solution which we can hope for in resolving this difficulty? What I would like to suggest to you may at first sound somewhat iconoclastic in view of the title of the Conference and in view of our purposes here. But I think it is a reasonable suggestion. For the type of data which can be gathered from the schools and classes in this country, with the resources available to us, it does not seem necessary at all to be concerned with the selection of a term, nor the selection of a particular cutoff point on the audiometric scale above which you will accept and below which you will reject persons as "deaf."

The solution I would suggest is one which is certainly widely used in other disciplines and has been successful in many similar cases; that is, that we identify those factors which are important, those factors on which data are desirable, and then measure those factors and report the results of those measurements. Such a report might take a form along these lines: A particular school in reporting might state that there are 35 children with losses in excess of 90 decibels, 50 children with losses from 80 to 90 decibels, 25 with losses from 70 to 80, and 60 with losses from 60 to 70 decibels. (I am avoiding here all of the necessary qualifications with which you are familiar: in given frequencies, under particular conditions of testing, etc.)

In conveying such information, a school superintendent need have no concern that there will be any misunderstanding as to what he meant when he said that his was a school for the deaf. It is obvious that, insofar as this most sticky point, degree of loss, is concerned, he includes children with losses from 60 decibels up. Perhaps the next school superintendent feels that for his own purposes he does not wish to accept children with losses less severe than 70 decibels. That administrative decision would present no communication problem. He would simply report that he has so many children from 70 to 80 decibels, so many from 80 to 90, and so on.

Not only is information in this form conveyed from one discipline to another with a minimum of ambiguity (granting, of course, the standardization of test conditions, etc.), but its usefulness over time is enhanced. Today we may consider children with losses of 70 decibels as having an irremedial condition; tomorrow we may find techniques which would alter this particular conclusion. It would no longer matter for reporting purposes if that data were tied--operationally, if you will--to the audiometer.

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[1] *Roger G. Barker, Beatrice A. Wright, Lee Meyerson and Mollie R. Gonick,* Adjustment to Physical Handicap and Illness: A Survey of the Social Psychology of Physique and Disability. *Rev. ed.; New York: Social Science Research Council, 1953. p. 440.*

Similarly, we can deal with each of the remaining factors with which we may be concerned. We do not have difficulty being understood when we state that a child lost his hearing at 3 months, or 3 years, or 6 years of age. We do have some difficulty if we try to tell people that the hearing loss occurred "prelingually." In preparing a table giving age at onset of loss for Gallaudet students, I elected to label those who lost their hearing at or before 3 years of age "prelingually deaf." The person to whom I sent the data replied immediately that the term was a misnomer, because the development of speech begins prior to *one* year of age! How much better it would have been to have reported the number of losses at 1 year, 2 years, 3 years, etc.

What this all boils down to is the suggestion that rather than defining deafness, we should describe it. In the initial stages of building a reporting system, we need not dissipate substantial energy in what may turn out to be a mere quibbling over terms. A description in some detail of children now in schools and classes for the hearing impaired will be very useful in itself, and it will also lead most naturally to an empirically derived classification system best fitting the facts. The eventual goal of this statistical program is not the creation of a neat set of figures; it is to provide information which can, in a multitude of ways, assist those who work with these children to make better decisions. At our present level of sophistication we can overcome what each of the preceding speakers has mentioned as the serious problem of defining deafness: not by delimiting the term, but by describing the condition.

## Appendix B-1

## DEFINITIONS OF DEAFNESS BY DISCIPLINES

### 1. *Common Parlance*

"Congenital or acquired lack, loss, or impairment of the sense of hearing whether due to defects in *(1)* the sound-transmitting mechanism, *(2)* the organ of Corti or auditory nerve, or *(3)* the interpretative centers of the brain--called also respectively *(1) transmission deafness*, *conduction deafness*, or *conductive deafness*, *(2) perceptive deafness* or *nerve deafness*, and *(3) central deafness*, *cortical deafness*, or *psychic deafness."--Webster's Third New International Dictionary of the English Language*, Unabridged. Springfield, Mass.: Merriman, 1964, p. 581.

## 2. *Demography*

A. *"Deaf-mute.* Include as a *deaf-mute (1)* any child under eight years of age who is totally deaf, and *(2)* any older person who has been totally deaf from childhood or was born deaf. Do not include a person who became deaf after the age of eight from accident, or from disease, or from old age. A person is to be considered as totally deaf who cannot understand loudly shouted conversation or can understand it only with the aid of an ear trumpet or other mechanical device. In case of infants or young children not old enough to understand conversation, the test should be whether they apparently hear when addressed in a loud tone of voice."--U.S. Bureau of the Census. *The Blind and Deaf-Mutes in the United States: 1930.* Washington, D.C.: U.S. Government Printing Office, 1931, p. 2.

B. Specific rules employed by enumerators. Definitions and accessory procedures in exact detail governing the enumeration of deafness were as follows: (a) The enumerator asked whether any member of the household is deaf. If the answer was "No," he passed on to the next schedule item; if the answer was "Yes," he was required to specify degree for each person, as determined from information elicited by asking further questions. (b) In characterizing degree, the following definitions were applied: i. partial deafness, stage one is defined as that preventing a person from understanding speech at the theatre, in church, or at a conference of five or six people; ii. partial deafness, stage two is defined as that preventing a person from understanding someone speaking to him from a distance 2 or 3 feet directly in front of him; iii. partial deafness, stage three is defined as that preventing a person from understanding speech over the telephone; iv. total deafness is defined as that preventing a person from understanding speech under any conditions; v. deaf-mute is a person who was born deaf or acquired severe deafness at such an early age that he did not learn to speak. (c) Enumerators were instructed not to ask whether any member of the household is "partially" deaf; this information was to be recorded only if given voluntarily. (d) Degree of deafness was ascertained independently of any consideration of benefits derived from mechanical (or electrical) hearing aids or from lipreading.

Since enumerators were cautioned not to encourage informants in the reporting of deafness cases, it is expected that for the survey as a whole an underenumeration of moderate degrees of deafness was obtained. Exclusion of beneficial aids in determining degrees should result in the reporting of deafness cases strictly on the basis of the degree of social handicap involved.--National Health Survey (1935-36). Preliminary

Reports: Hearing Study Series Bulletin No. 1. Washington, D.C.: U.S. Public Health Service, 1938, pp. 12-13.

C. "Accordingly, a person is to be looked upon as such in whom the sense of hearing is wholly or practically wholly absent or nonexistent, or who is in possession of hearing too slight to be of material service, or to be of avail for the understanding of spoken language; or in whom there exists little or no sound perception (even with mechanical devices or other artificial recourse), or who is not responsive to sounds addressed to the ear; or who does not recognize the sound of the human voice or other sounds loud in volume issuing nearby; or who has not sufficient aural power for the ordinary affairs of life--and who at the same time, and largely in consequence of the aforesaid conditions is without the faculty of speech, or is more or less deficient in speech--such speech as exists departing in greater or less recognized measure from the normal or usual speech of human society, or from that in use by persons having the faculty of hearing, or from that employed as an effective means of communication, and so far as it exists, such speech having in general to be acquired or having had to be retained in the form in which it now appears, only by special instruction and training--with the result that this speech is a more or less artificial one."--H. Best. *Deafness and the Deaf in the United States.* New York: Macmillan, 1943, p. 125.

### 3. *Audiology*

A. "From the audiological point of view, a person who has a hearing loss approaching 75 decibels across the speech range is likely to need special techniques for the development of expressive communication, and we can perhaps specify what those techniques should be. The audiologist also tries to assess the deaf person's ability to receive communication. From the standpoint of the staff of the Hearing and Speech Center, the deaf person, audiologically speaking, is one who does not use hearing in a reliable way with the best of amplification; one who understands very little, if anything, through hearing alone; one who is basically visually oriented."--D. R. Frisina, "Introductory Remarks," *American Annals of the Deaf,* 107:469 (1962).

B. "We propose to confine the term 'deafness' to hearing levels for speech of 82 db or worse. A good reason for selecting this particular boundary is that the most authoritative rule for estimating the handicap imposed by hearing loss reads 'the handicap [for hearing of everyday speech] is considered total at 82 db hearing loss for speech.' Our criterion thus has medical sanction in a social and economic context."--H. Davis and S. R. Silverman. *Hearing and Deafness.* New York: Holt, Rinehart and Winston, 1960, p. 81.

## 4. *Education*

A. "The deaf are those who were born either totally deaf or sufficiently deaf to prevent the establishment of speech and natural language; those who became deaf in childhood before speech and language were established; or those who became deaf in childhood so soon after the natural establishment of speech and language that the ability to speak and understand speech and language has been practically lost to them.

"The hard of hearing are those who have established speech and ability to understand speech and language, and subsequently developed impairment of hearing. These children are sound conscious and have a normal, or almost normal, attitude toward the world of sound in which they live."--White House Conference on Child Health and Protection. *Special Education, The Handicapped and the Gifted.* Report of the Committee on Special Classes (Section III, Education and Training), Vol. III-F. New York: Century, 1931, p. 277.

B. "The deaf: those in whom the sense of hearing is nonfunctional for the ordinary purposes of life. This general group is made up of two distinct classes based entirely on the time of the loss of hearing: (a) the congenitally deaf--those who were born deaf; (b) the adventitiously deaf--those who were born with normal hearing, but in whom the sense of hearing is nonfunctional through later illness or accident.

"The hard of hearing: those in whom the sense of hearing, although defective, is functional with or without a hearing aid."--Conference of Executives of American Schools for the Deaf, "Report of the Conference Committee on Nomenclature," *American Annals of the Deaf,* 83:1-3 (1938).

C. "The *deaf* are those in whom the sense of hearing, either with or without a hearing aid, is insufficient for interpreting speech. The *prelanguage deaf* are those in whom deafness *preceded* a firm establishment of language and speech. The *postlanguage deaf* are those in whom deafness occurred *after* good language and speech had been acquired.

"The *hard of hearing* are those in whom the loss of hearing is educationally significant, but whose residual hearing is sufficient for interpreting speech with--if not without--a hearing aid.

"A *natural-language group* is one composed of the hard of hearing and those postlanguage deaf who have retained their normally acquired speech and language."--H. Z. Wooden. "Deaf and Hard of Hearing Children," in L. M. Dunn, *Exceptional Children in the Schools.* New York: Holt, Rinehart and Winston, 1963, p. 344.

## 5. *Medicine*

A. "Ideally, hearing impairment should be evaluated in terms of ability to hear everyday speech under everyday conditions. . ."--Guide for the Evaluation of Hearing Impairment. *Transactions of the American Academy of Ophthalmology and Otolaryngology*. 63:236-8 (1959).

B. "At the other extreme of the hearing range, there may be a total loss of hearing or a total inability to hear speech. As commonly used, these terms are not precise nor necessarily synonymous. It is important to define them and to determine the relation between them. This cannot be done until more experimental data are available." Council on Physical Medicine and Rehabilitation, "Report of the Council," *Journal of the American Medical Association*. 157:1408-9 (1955).

C. "Deafness. "Lack or loss, complete or partial, of the sense of hearing." Dorland's Illustrated Medical Dictionary. Twenty-third ed., Philadelphia: Saunders, 1957, p. 354.

## 6. *Military Services*

"Cases of true deafness involving a hearing level in the better ear of 60 db or more in the speech range."--U.S. Army AR 40-530-55. *Auditory Evaluation of Members on Active Duty*. Cited in H. Davis and S. R. Silverman, *Hearing and Deafness*. New York: Holt, Rinehart and Winston, 1960, p. 245.

## 7. *Psychology*

A. "As to the diagnostic criteria to be used in classifying the literate deaf in our main sample, deafness was defined as a *stress-producing hearing loss, from birth or early childhood, rendering a person incapable of effecting meaningful and substantial auditory contact with the environment.*"--J. D. Rainer, K. Z. Altshuler, F. J. Kallmann, and W. E. Deming (eds.). *Family and Mental Health Problems in a Deaf Population*. New York: Department of Medical Genetics, N.Y. State Psychiatric Institute, Columbia University, 1963, p. xiv.

B. "This is the situation that characterizes the smallest but most unusual section of the hearing-impaired population, numbering less than one quarter of a million persons throughout the country. Commonly known as 'deaf-mutes' or the 'deaf and dumb,' its members are technically termed 'the deaf.' They are not mute, for there is no vocal impairment. Neither are they dumb, for many are taught to speak through special instructional techniques. The great handicap of the deaf lies in the fact that permanently impaired hearing occurs during the most vulnerable time of life--from birth through early childhood--and is so severe that it deadens the most powerful developmental stimulus of all--the sound of the human voice." (p. 28).

"In the preceding chapter, discussion was centered upon the smallest category of acoustically disabled persons--the deaf. The present section deals with the largest, made up of several million individuals who are technically termed 'the hard of hearing.' Two major subgroups of this vast body will be considered here as further illustration of the multiple implications of hearing loss. They are (a) the progressively deafened and (b) the suddenly deafened in adulthood.

"Whereas the problems of the deaf illustrate the results of severe auditory dysfunction since birth or early childhood, those of the progressively deafened demonstrate the results of slow, gradual loss of hearing that may begin at any time of life." (p. 56)--E. S. Levine. *The Psychology of Deafness.* New York: Columbia University Press, 1960.

C. "In the psychology of deafness it is generally assumed that the hearing loss has resulted from peripheral nervous system involvement, in which case a reciprocal relationship exists between the type and the cause of the deafness. If the type, sensory-neural or conductive, can be established, an inference can be made concerning the cause. Likewise, if the cause can be determined an inference can be made concerning the type. Moreover, postulations as to the type of deafness can be made when it has been determined that the condition is exogenous, congenital or acquired, and when it is known that the person is deaf or hard of hearing. Establishing the etiology also has implications for the psychological effects which might follow. . . (p. 29).

"All degrees of hearing loss are founded in the sensory-neural group. However, in general those with conductive deafness classify as hard of hearing while those with sensory-neural loss include many with profound or total deafness." (p. 40).

"Deafness occurs because of three major types of disorders. The one which is most frequent, and to which the data in the following sections pertain, is that which results from peripheral nervous system defects, from end-organ deficiencies. The other types are central and psychogenic deafness." (p. 41)--H. R. Myklebust. *The Psychology of Deafness.* New York: Grune & Stratton, 1960.

## Discussion

Dr. Schwartz indicated that he was not clear as to whether Dr. Schein was rejecting the concept of a single criteria of deafness in favor of another concept which might include either multiple parameters or an audiometric definition which would include different gradations of deafness. In reply, Dr. Schein said that he would prefer not to recommend the audiometric definition alone but would rather suggest that selection be made from relevant variables, that is, those which appear to be of greatest concern. He indicated that the age concept will be one without question, for it can be reported in measurable terms. He suggested that the hearing levels for children in schools for the deaf be simply reported. Then when all the statistics on these children have been gathered, the picture of what deafness means to those now using the term will emerge from such a report. He further indicated that he had spoken only about audiometric level because it seemed to him to be the single greatest bone of contention. But the same would apply in terms of other factors that might be selected, such as age of onset.

He would prefer to report statistically the audiometric levels with so many children whose age of onset was congenital, so many whose age of onset was in the first year of life, etc. Dr. Schein indicated a concern for the degree of hearing loss, specifying the conditions without concern for the label. He emphasized that what he was suggesting was, rather than being concerned with a term, that the degree of loss be reported. All the various degrees of deafness should not be covered by a single term. Similarly, he did not believe that everybody who falls in the hearing loss category between 15 and 70 decibels should be lumped together as "hard of hearing." In essence, he felt that deafness not be defined but rather that the whole range of hearing loss be reported or that portion of the range which is used for the population with which concern is felt. For a great number of practical purposes and for all heuristic purposes, it would be useful to report the number of persons at each given point on the audiometric scale.

Dr. Schwartz replied by indicating that he was not really clear on why age of onset and some of the other criteria alluded to by Dr. Schein, besides audiometry, would legitimately fit into a definition of deafness. He believed that these might be qualifying characteristics of deafness but that the basic fundamental understanding referred to audiometry. He added that if a primary objective of deafness reporting were to determine prevalence, as had been indicated, then it would be necessary to adopt a compromise definition for the purpose of enumerating cases.

Mr. Hedgecock said that he was interested in Dr. Schein's report of the study that made it appear that questionnaires of self-evaluation can do a reasonably good job of delineating the degree of difficulty and deafness. He wondered whether a questionnaire could be used on a census-wide basis in determining those individuals who have hearing loss. Dr. Schein stated that there might be even greater problems in defining a "reasonably good job" than in defining "deafness." It did seem from the two studies quoted that it is possible to get fairly good estimates of hearing levels in the general population from self-report studies. These are not estimates that would permit the discarding of audiometers, but they give some fairly good ideas of prevalence of hearing loss. Although it was possible to assess audiometric levels in schools and classes for the deaf, such was not the case for the population as a whole in the studies using the Gallaudet Hearing Scale.

Dr. Schein indicated that what he had suggested is that it is possible to get some good estimates of hearing impairment from studies such as the National Health Survey annually conducts. This is so if one is not completely concerned with the problem of saying who is deaf and who is hard of hearing, and with the problem of what is severe or moderate hearing loss. If this were the case, it would then be necessary to validate the questionnaire data with audiometric studies of the general population along the lines of the studies of deaf students reported above.

Dr. Ventry wanted to know what practical or educational implications the data would have if one knew that there are a million children with a hearing loss between 50 and 60 decibels. In other words, what is the next step after such data are collected? Dr. Schein replied that in planning facilities for the education of the deaf this was particularly important. It is an acute problem, for instance, at Gallaudet College. Deciding on howmany new dormitories one must need is obviously going to be a function of deciding how many children there are who would need such facilities. Beyond that, the Vocational Rehabilitation Administration would like to know what they should be requesting in the way of appropriations from Congress. In general, these were the lines along which he had been thinking with respect to his suggestion.

Mr. Graham indicated to Dr. Schein that the latter, in stating the need to identify factors that seemed important for a description of deafness, had mentioned audiological measurement only as an example. Mr. Graham wanted to know whether it was meant that other factors could serve as a substitute for audiological measurement in the definition. Or, was Dr. Schein suggesting the use of certain audiological measurement in combination with other information, such as age of onset, prelingually or postlingually, and so forth, as a composite definition of deafness. If this were so, he wanted to know what kinds of problems this would pose for the statistics being mentioned. He was concerned with the possibility of getting too many different kinds of combinations so that it wouldn't be very meaningful. He suggested the use of audiometric findings as the basic criteria for the definition and possibly the use of the other measurements as modifiers.

Dr. Schein replied that there were a number of factors which are of concern and he was not suggesting an attempt to reincorporate these into a single word that would represent anything. The selection of which factors were of interest would vary with the group concerned with the problem. What he was suggesting was that each group report that which is relevant to its particular specialty. In rehabilitation it is of great concern to know the hearing level of the individual. However, it really is not of too great concern as to whether he lost his hearing at 3 or 4 or 5 years of age. The important question to answer is whether the young adult who comes in for rehabilitation can communicate or not and how well he does, since this will determine, in part, the limit within which employment can be found for him. Not only is the audiometric level of great importance but one would also like to know of the individual's use of a hearing aid and how well he tolerates amplification. It is of interest to know if he had had auditory training and whether he is making the greatest use of amplification that he can make.

All definitions of deafness agree that a hearing loss is involved. Disagreement arises when one is concerned with how much of a hearing loss constitutes deafness. The suggestion then is that the profession talk not about deafness but about hearing level. Dr. Schein concluded that perhaps the best approach was to take the audiometric reference point as the major categorical variable. However, there was nothing to prevent anyone from adding to that as many cross-variables as data permit.

# TRACHOMA*

Georges H. Werner
Bachisio Latte
Andrea Contini

Nearly 500 million people--more than a sixth of the world's population--are infected with the blinding eye disease known since ancient Greek times as trachoma. Trachoma is endemic in many parts of Asia, Africa, Europe, South America and among Indians in the United States. Afflicting mainly the peoples of underdeveloped areas, the infection could probably be eliminated by the improvement of their hygiene, housing and nutrition. But the disease is a cause as well as a consequence of their poverty; it is part of the vicious circle that makes the development of the underdeveloped countries so difficult. A successful medical attack on trachoma would not only remove a vast burden of human suffering but also help to put the struggling nations on the road to a decent level of living.

It is only within the past six years that investigators have positively identified the cause of trachoma. The agent of the disease is a virus, or near virus, markedly similar to those responsible for psittacosis ("parrot fever") and the venereal disease lymphogranuloma venereum. This knowledge offers the exciting prospect that it may be possible to control the disease by vaccination and thus bring to an end its long career as a major scourge of mankind.

Trachoma was given its name by the first-century Greek physician Dioscorides in his famous *De Materia Medica*. The name comes from the Greek word *trachys*, meaning "rough," and this describes the most striking symptom of the disease: a roughening of the conjunctiva, the delicate lining of the eyelids. The disease starts with a mild inflammation of the conjunctiva of the upper eyelid. It proceeds to form many small follicles; these granulations may go on growing until the conjunctiva is as rough and pitted as the skin of an orange. Eventually the damage may extend to the eye's cornea and produce partial or total blindness.

In countries where the infection is prevalent it commonly attacks children at an early age. Trachoma is highly contagious, and it can be transmitted from person to person by flies, in water or, most often, by direct contact between the members of a family. Some ethnic groups seem to be more susceptible than others; Arabs, for example, have a higher incidence of the disease than Negroes in the same area. Climate also seems to be a factor: trachoma is most common in warm climates, near seacoasts and in windy desert areas, where

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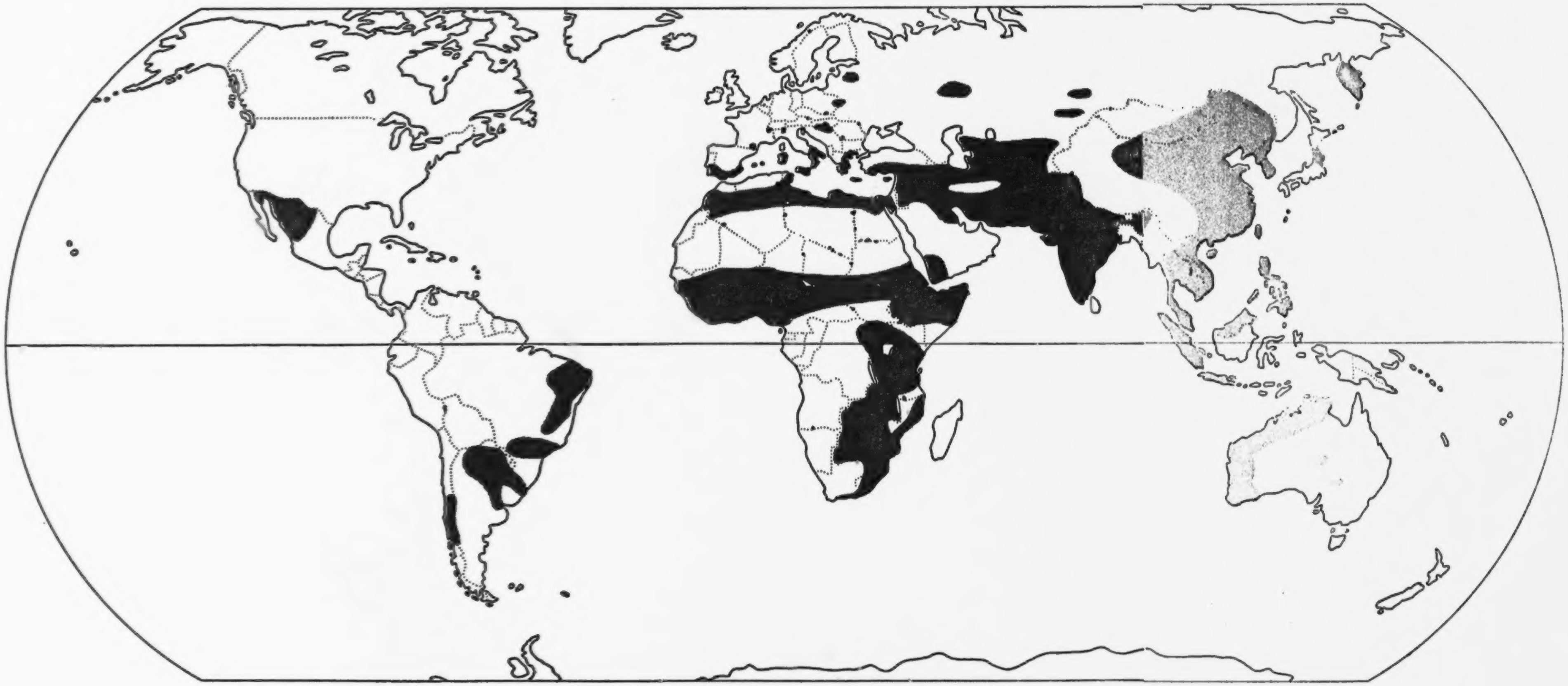
irritation of the conjunctiva by sand particles in the air may sensitize it to infection. None of these conditions, however, plays a decisive role. The one common denominator that characterizes all the populations in which the disease is widespread is a low standard of living, with the accompaniments of undernourishment and insanitary conditions, such as ritual ablutions by many people with the same water and use of the same towel by all the members of the family.

Trachoma, easily identified by its symptoms, was described by the Sumerians in the fifth millennium B.C. and is reported in records of ancient China as early as the third millennium B.C. It was probably the most common eye disease in ancient Greece and in the Roman Empire. Armies and traders spread it from population to population. During the Middle Ages, Arab invaders and crusaders returning from the Middle East kindled epidemics of trachoma in Europe. Similarly, during the first half of the 19th century a new European outbreak of the disease was generated by Napoleon's soldiers on their return from his campaign in Egypt. Trachoma flared up again in some areas of eastern Europe during World War I and II.

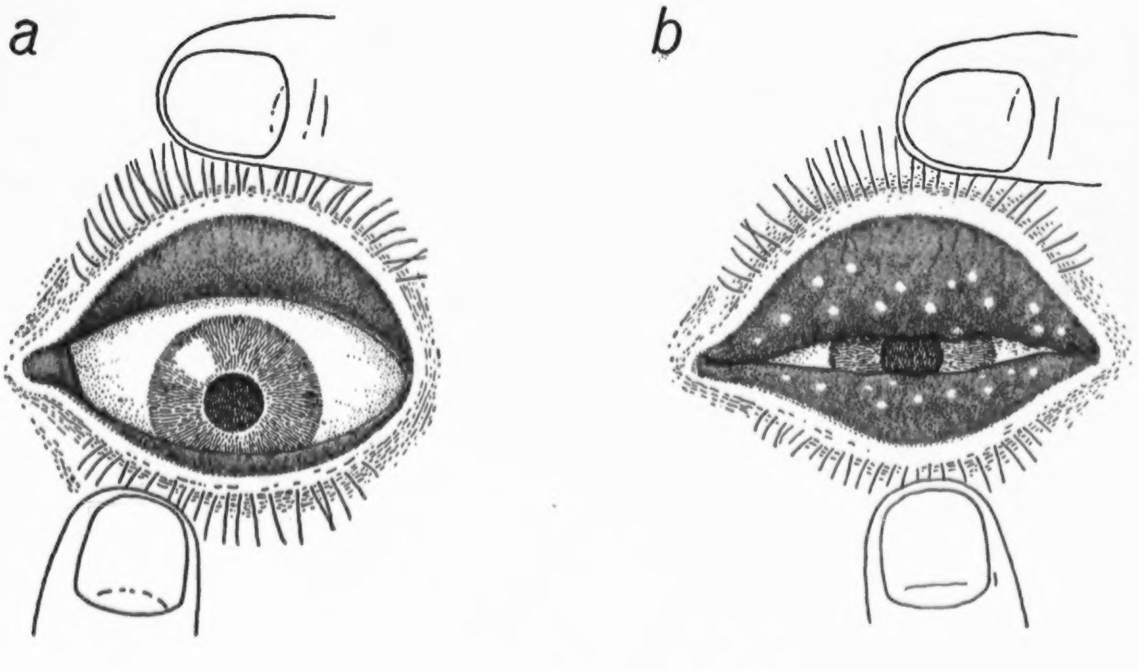
Egypt is still a virulent focus of the disease. The virus has infected most of the inhabitants of that country: practically all the children in the villages get it before they are a year old and 90 percent of the children in the city slums are infected before the age of two. Egypt, however, is only one of many countries with a high incidence of trachoma [see illustration on next page]. It is prevalent throughout North Africa; in Tunisia, for example, 40 percent of the population have trachoma and 10 percent of the desert people living in oases are totally or almost totally blind, mainly because of this disease. Trachoma is also common in the rest of Africa, particularly in the Bantu tribes of South Africa, which have the highest proportion of blind people in the world.

In China (according to available statistics, which describe conditions prevailing about 20 years ago) trachoma attacks nearly 50 percent of the population: at least 100 million Chinese have had it in a severe form and 20 million are practically blind. In Vietnam the disease infects 30 percent of the population and blinds nearly 10 percent; in the Rajasthan province of India 50 percent of the children are infected before they enter school; in some areas of Iran the entire population is affected. In Europe trachoma is still a problem in Portugal, southeastern Spain, Sardinia, Sicily, Yugoslavia and southern Greece. In the Western Hemisphere the disease has a high incidence in parts of Brazil, Argentina and northewestern Mexico, where 30 to 60 percent of the school-age children are infected. In the United States the disease has all but disappeared from the "trachoma belt" that used to extend from West Virginia to Oklahoma, but the incidence is still high on some Indian reservations.



World distribution of trachoma is indicated by color in areas where at least 10 percent of school-age children are affected by the disease. Altogether nearly 500 million people of all ages throughout the world have trachoma. Many are blind from it. No color shows in the area of the U.S. but the disease occurs on a few Indian reservations.

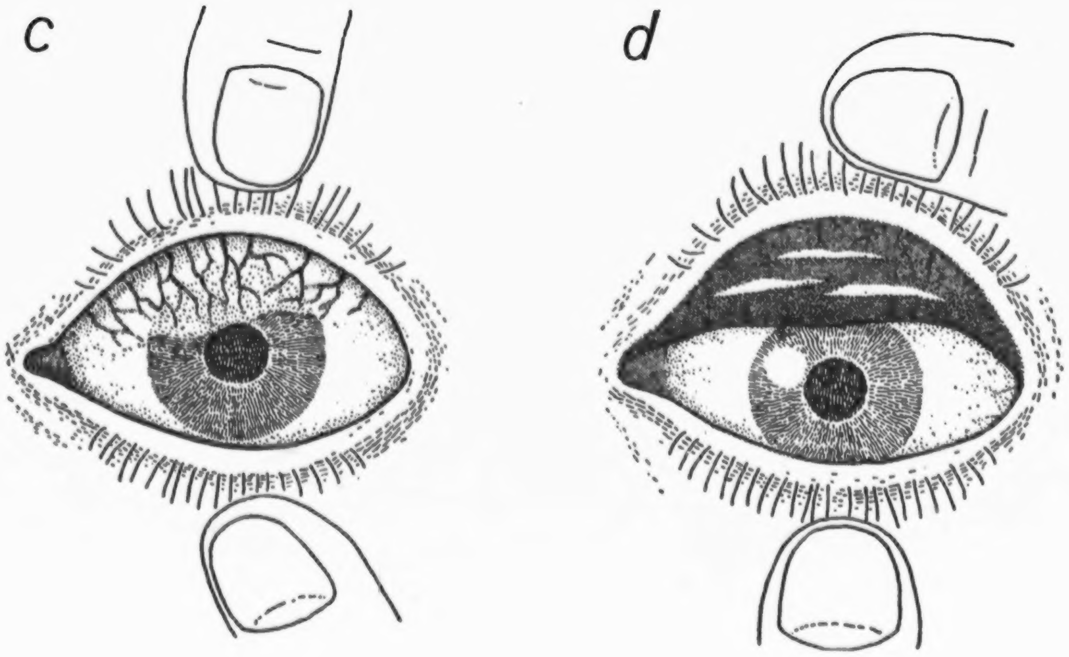
The classic symptoms of trachoma have been known for many centuries to physicians throughout the world. In a child who contracts the disease the first signs are a mild conjunctivitis, watering eyes, a feeling of heaviness of the upper eyelids, a slight aversion to light and frequent blinking. By turning out the inner side of the upper eyelids one can see small, whitish follicles in the lining and a network of capillary blood vessels forming around them. Sometimes the disease progresses no further and the conjunctivas heal spontaneously. In most cases, however, the infection, if untreated, steadily produces more and more damage, sometimes continuing throughout the sufferer's lifetime. The conjunctiva becomes rougher and rougher, with larger and more numerous follicles and nodules. The growing network of blood vessels invades the cornea and begins to form an opaque covering (called the pannus) over the eyeball. Scar tissue develops in the conjunctiva and cornea, further clouding the patient's vision. The eyelids become deformed and turn inward, eyelashes and all, so that they irritate the eyeball. Patients offer suffer excruciating pain, and the disease ends in varying degrees of impairment of vision up to total blindness. Another unhappy aspect of trachoma is that recovery from an infection does not confer immunity: the virus may repeatedly attack the same individual with increasingly serious effects.



*Changes in Eye that accompany trachoma are illustrated. In a, b and d the eyelids are turned back; in c the eye is merely held open. The eye in a is normal.*

The first clue to the nature of the causative agent of trachoma was discovered in 1907 by two Austrian physicians named S. von Prowazek and L. Halberstaedter who studied the disease in Java. They gently scraped some cells from the conjunctivas of trachoma patients and then stained the cells and examined them under the microscope. In the cytoplasm of the cells they found inclusions containing many tiny particles ("elementary bodies"), which they judged to be the organisms responsible for the disease. Their conclusion apparently was confirmed when they inoculated some of the scrapings from the patients into the conjunctivas of apes as an experiment: after a few days the apes' conjunctival cells showed the same elementary bodies. The infectious particles evidently had reproduced themselves in the new host.

The French bacteriologist Charles Nicolle followed up this finding. At the Pasteur Institute of Tunis, of which he was director, Nicolle and his associates set out in 1912 to try to identify further the trachoma organism. Suspecting that it was a virus, they applied what was at that time the standard test to determine the question. They ground up the conjunctival scrapings from a trachoma patient, suspended the ground material in liquid and passed it through a porcelain filter. The pore size of the filter was small enough to stop



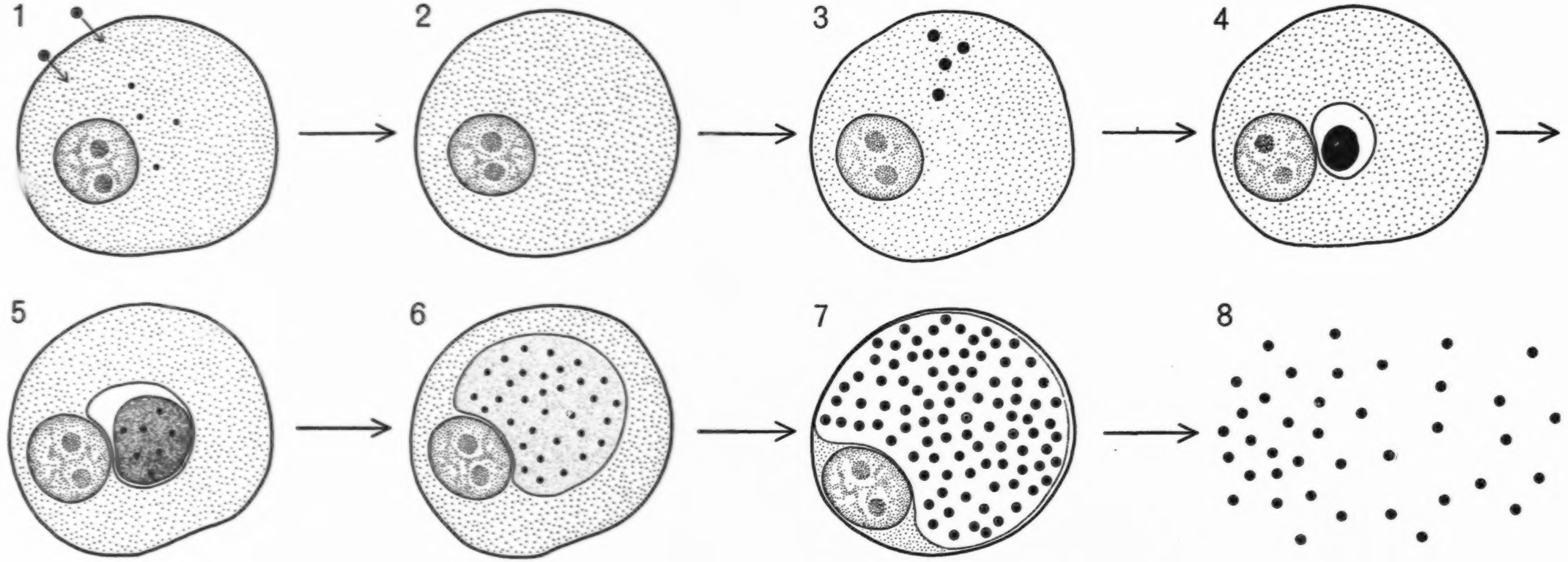
*In b typical trachoma follicles are shown. Pannus, a network of blood vessels, has begun to cover the eyeball in c. The white transversal scars of cicatricial trachoma are shown in d.*

bacteria and let through only smaller particles such as viruses. Nicolle then inoculated the filtrate in the conjunctivas of a chimpanzee and a macaque monkey. It produced a mild conjunctivitis in both. When scrapings from the eyelid linings of these animals were inoculated on the conjunctivas of human volunteers, the human subjects soon showed the typical early symptoms of trachoma. The Prowazek-Halberstaedter particles turned up in profusion in the volunteers' conjunctival cells.

The passage of the infection by means of the filtrate from man to animal to man gave strong evidence that the agent of trachoma was a virus. Other experimenters later confirmed Nicolle's results. This, however, was still a long way from identification of the virus. As in the case of other viruses attacking only primate animals (for example the virus of poliomyelitis), little progress could be made in investigating the agent of trachoma until it could be grown in cell cultures in the test tube or in relatively simple systems such as the developing chick embryo.

In the 1930's and 1940's virologists, notably Sir Samuel Bedson of the London Hospital and Karl F. Meyer of the San Francisco Medical Center of the University of California, learned that the agents of psittacosis and lymphogranuloma venereum multiplied in cells in much the same way as the agent of trachoma, producing similar bodies in the cytoplasm. They also found ways to cultivate those viruses in the yolk sac of fertilized chicken eggs. For many years, however, all attempts to grow the trachoma agent in the same way failed. Then in 1957 four virologists at the National Vaccine and Serum Institute in Peking finally succeeded. These workers, whose accomplishment can be ranked in importance with that of John F. Enders and his colleagues in achieving the test-tube cultivation of the polio virus, were F. F. T'ang, H. L. Chang, Y. T. Huang and K. C. Wang.

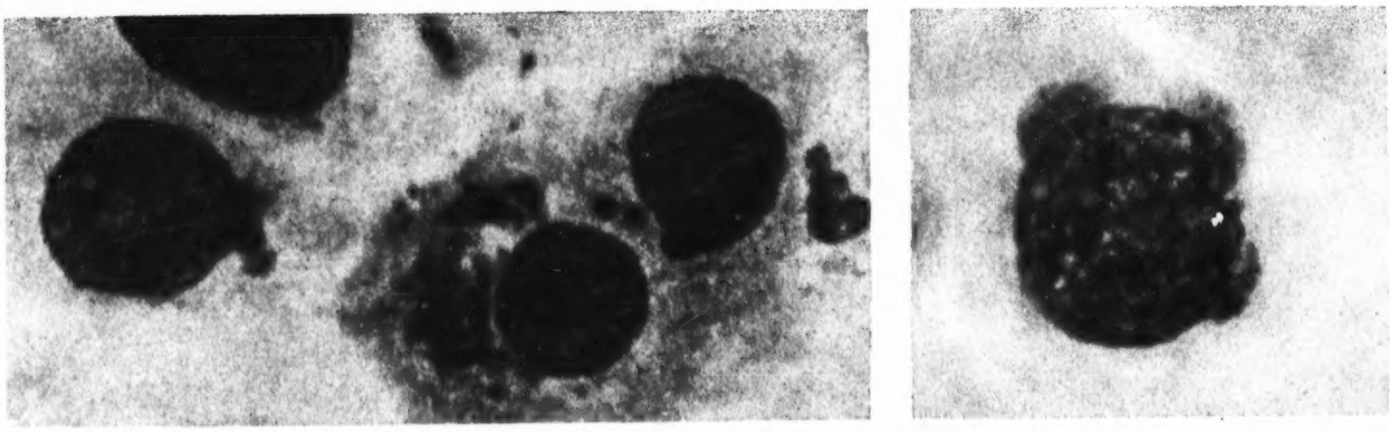
The key to the success of the Chinese workers was their precaution in eliminating bacteria and other organisms in the culture that would mask or prevent the propagation of the trachoma agent itself. Various bacteria are commonly present in the human conjunctiva. T'ang and his co-workers, after taking conjunctival scrapings from trachoma patients, treated the material with streptomycin to inactivate the bacteria. They then inoculated the scrapings into the yolk sac of chick embryos that had been incubated for six to eight days. From a total of 93 such cultures they managed to produce three that gave positive evidence of propagation of the trachoma agent in the cells of the yolk. The typical Prowazek-Halberstaedter bodies, characteristic of the trachoma infection, showed up clearly in the cytoplasm of these cells [see illustration on following page]. Furthermore, this material, after a series of passages in chick embryos, produced conjunctivitis in rhesus monkeys.



*Trachoma-Agent life cycle requires living host cell. Cycle begins when agent sheds protein coat as its DNA enters cell (1). An "eclipse phase" follows, when no infectious particle can be recovered from the cell (2). After about three hours RNA particles begin to appear in the cytoplasm (3); they grow until they form a mass (4) called an inclusion body, which is found within a vacuole that appears in the cytoplasm. Some 25 hours after infection new DNA particles begin to appear in the inclusion bodies (5). Their number increases, the inclusion body grows (6) and finally the body fills the whole cell (7); it crowds the nucleus against the cell wall. The DNA particles acquire protein coats at this stage, and then, 70 hours after infection, they burst out of cell (8) and go on to infect adjacent cells in a similar manner. The process is typical of virus infections.*

The following year two British bacteriologists, H. L. Collier and J. Sowa of the Lister Institute of Preventive Medicine in London, confirmed and extended the Chinese workers' discovery. Using the same technique, they cultivated the virus present in scrapings from trachoma patients in the West African country of Gambia. The material they cultured, when tested in a blind human volunteer, produced the characteristic clinical and microscopic signs of trachoma.

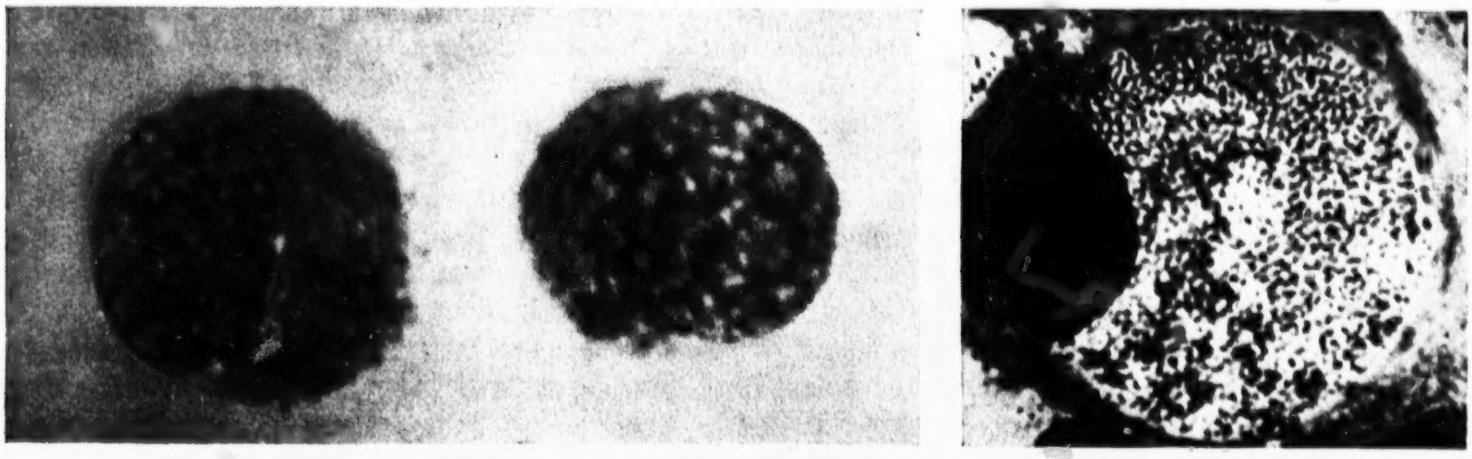
Since 1958 many workers have isolated the same agent from trachoma patients in Israel, Saudi Arabia, Egypt, Sardinia, California, Taiwan, Tunisia, South Africa, Australia, Portugal, Japan, India, Yugoslavia and other areas where the disease is endemic. Armed with the discovery that the organism can be grown not only in the yolk sac of fertile chicken eggs but also in human cells in vitro, a number of laboratories are pursuing an intensive study of the biology of the trachoma agent. In the past three years investigations at the Lister Institute, the Hadassah Medical School in Jerusalem, Tokushima University in Japan and the medical schools of the University of California, the University of Texas, the University of Chicago and Notre Dame University have shed much light on the nature of the organism and the way it multiplies in the living cell.



*Inclusion bodies in cells from eyelids of trachoma patients are shown in photomicrographs by the authors. At left, they are the black spots near nuclei of cells. Next, three larger crescent-shaped bodies are growing around a nucleus. The third photomicrograph shows large bodies surrounding nuclei*

The trachoma agent has been found to belong to a family of virus-like agents called Bedsonia (after Bedson, who did pioneering work on them). This ground includes both the organisms causing psittacosis and lymphogranuloma venereum and those responsible for certain pneumonias and other diseases of animals. The Bedsonia agents meet the definition of a virus because they can multiply only in living cells. They are, however, somewhat larger than any other animal virus and, unlike other viruses but like bacteria, they are sensitive to the effect of sulfonamide drugs and antibiotics.

In its proliferation in the cell the trachoma agent shows all the characteristic behavior of a virus. The organism consists essentially of a core of deoxyribonucleic acid (DNA) enclosed by a coat of protein. In the act of penetrating the cell the agent divests itself of its protein. The naked DNA then initiates a sequence of chemical syntheses in the cell's cytoplasm. Particles of ribonucleic acid (RNA) arise near the cell nucleus. As they grow they form an "inclusion body" that eventually engulfs practically all the cytoplasm and produces a number of new DNA particles. The DNA particles then clothe themselves in protein coats and, some 70 hours after the invasion of the original single particle, burst out of the cell



*like skullcaps. At right a mature inclusion body, packed with new trachoma agents, fills a cell. Staining has made nucleus appear black. Magnification in all four photographs is approximately 2,000 diameters.*

as viruses ready to infect adjacent cells. Presumably the original DNA acted as a template for the synthesis first of RNA and then of the full-fledged DNA-plus-protein virus.

Although the agent produces trachoma only in man, experiments have shown that it can develop toxic or pathological effects of one kind or another in various animals. For instance, Samuel D. Bell, Jr., and his associates at the Harvard Medical School have shown that some strains of the trachoma agent will kill mice within 24 hours after being injected into the bloodstream and within a few days after being injected into the brain. In our laboratory at the Rhone-Poulenc Research Center we have noted that injection of a very small dose of the agent into the brain causes the mice to lose weight rapidly. In white rabbits the inoculation of some strains of the agent into the skin causes inflammatory nodules to form there.

Before 1938 the only treatment of any value for trachoma was the application of a solution of copper sulfate as a wash for the conjunctiva. Since then clinical investigators, following the pioneering work of G. B. Bietti of the University of Rome, have discovered, and laboratory studies of the agent have confirmed, that the organism is vulnerable to sulfonamide drugs, to tetracycline antibiotics (aureomycin, terramycin and others) and to some other antibiotics (erythromycin and spiramycin). The sulfa drugs, taken orally, inhibit the multiplication of the agent, and the antibiotics rapidly kill it when applied locally to the eye in the form of drops or ointment. The combined sulfonamide-antibiotic treatment is highly successful in curing the disease if it is caught early, particularly in children.

In Sardinia and other areas with sufficient medical resources trachoma has been all but halted by systematic treatment of all infected school children with the drugs. The World Health Organization has undertaken to assist 15 countries in programs of chemotherapeutic control of the disease. The treatment of a patient takes several weeks, however, and a community-wide campaign is costly--too costly for underdeveloped areas and too difficult for nomadic populations. Moreover, it is doubtful that even a massive effort, assuming that funds are available, could cope effectively with the disease in countries where the standard of living remains low. In such an environment a child is cured only to be reinfected by his continuing contact with the contaminated population.

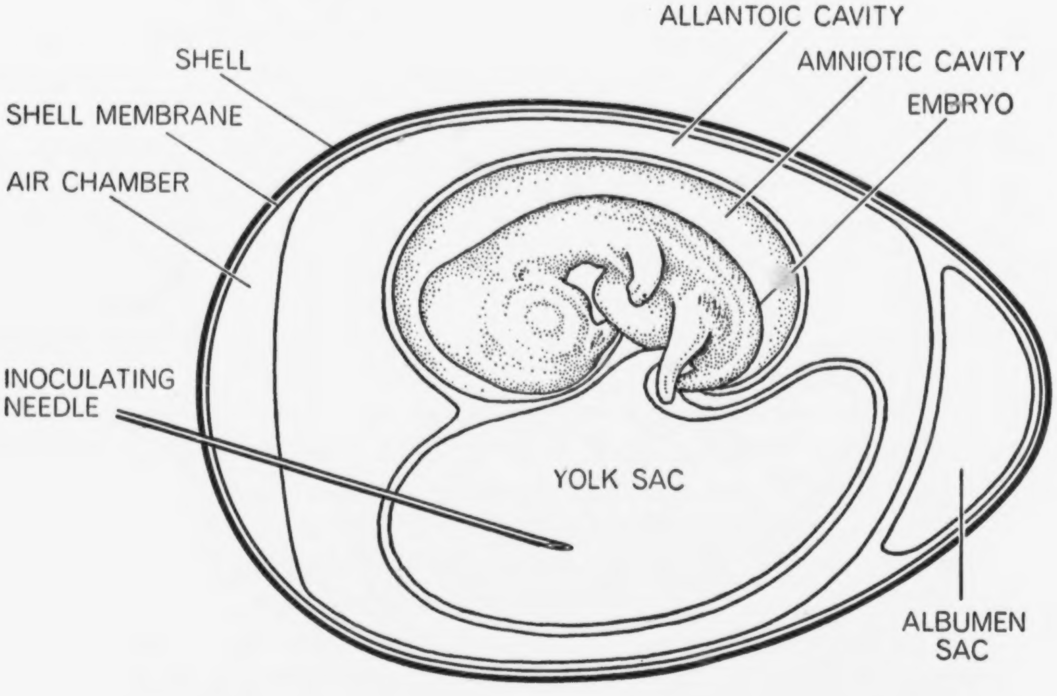
Thus chemotherapy, effective as it is, offers little hope at present for any marked reduction of trachoma on a worldwide basis. Immunization, on the other hand, would surmount the problem of exposure to the agent and could be applied on a large scale without great cost. Much of the present research therefore is directed toward the goal of finding an effective vaccine against trachoma.

This might seem a vain hope in view of the fact that the infection normally gives a patient no immunity against repeated reinfection. The common human experience in this respect has been borne out by experiments with other primates: monkeys can be infected with the trachoma agent again and again, and each time their conjunctivitis is no less severe than the time before.

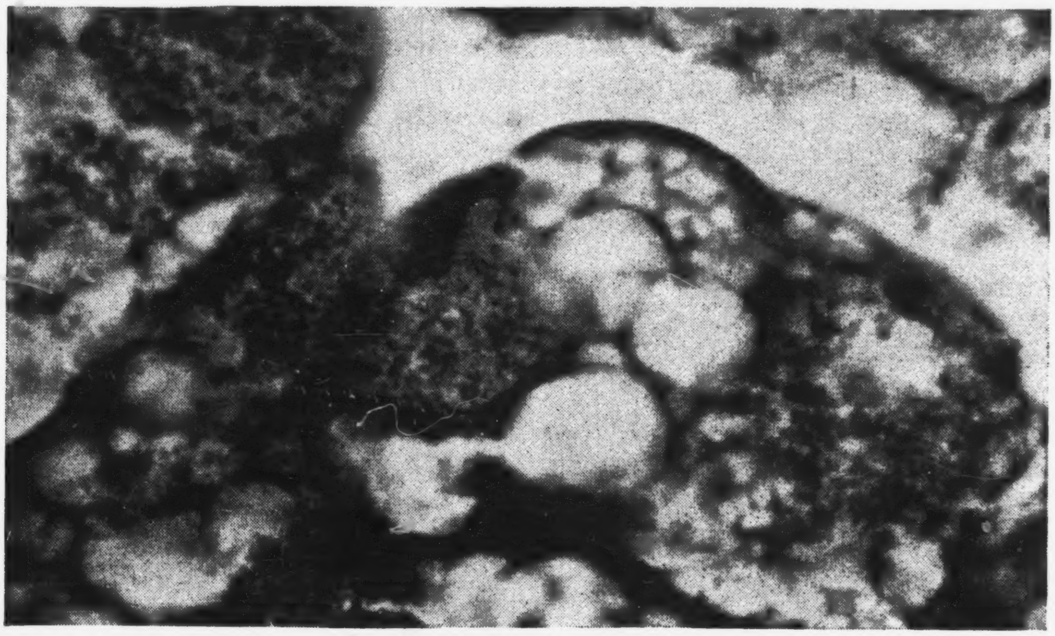
Yet such a situation need not discourage searchers for a vaccine; indeed, it adds interest to the challenge. In the case of trachoma the normal lack of immunity is open to at least two possible explanations that offer loopholes for attacking the problem. First, the trachoma agent may fail to evoke the manufacture of defensive antibodies by the host because it is a local infection confined to the tissues of the eye. In that case it might be possible to stimulate the formation of antibodies by injecting the trachoma antigen intramuscularly or subcutaneously. Second, there may be several varieties of the trachoma organism, each unaffected by the antibodies against the others, so that each in effect is a new infection. Indeed, it has been established that the agent has several strains and that there are at least two distinctly different types from the standpoint of antigenic structure.

By various stratagems investigators have in fact succeeded in experimentally immunizing animals against the trachoma agent. Bell's group at Harvard inactivated the organism with formalin, injected this vaccine intravenously in mice and found that it protected the mice against later injections of lethal doses of the live agent. We have made mice similarly immune to lethal or toxic doses in the brain by vaccinating them first with small intracerebral injections of the live agent; we were able to protect the mice, although less effectively, even with injections of the formalin-inactivated agent in the abdominal cavity. Chandler R. Dawson and his associates at the San Francisco Medical Center of the University of California have successfully vaccinated monkeys with the live organism injected into muscle. And Collier at the Lister Institute has been able to weaken some strains of the trachoma agent (by a series of passages in chick-embryo cultures) so that they produce no sign of disease when inoculated in the conjunctiva of a baboon.

Some vaccination attempts against trachoma have already been made in human patients with encouraging results. John C. Snyder and his co-workers at the Harvard School of Public Health made a small test with two volunteers. They gave one a subcutaneous injection of the formalin-inactivated organism, and six months later they inoculated the conjunctivas of both subjects with the live agent. The trachoma symptoms of the vaccinated individual were definitely less severe than those of the unvaccinated one. In a similar trial in Ethiopia A. Felici and R. Vozza of the Istituto Superiore di Sanita in Rome also found that vaccinated volunteers were more resistant


ALLANTOIC CAVITY
SHELL
AMNIOTIC CAVITY
EMBRYO
SHELL MEMBRANE
AIR CHAMBER
INOCULATING NEEDLE
YOLK SAC
ALBUMEN SAC

*Chick embryo is widely used as culture medium for viral agents. The trachoma agent grows well in the cells of the yolk sac. In this diagram the sac is shown being inoculated.*

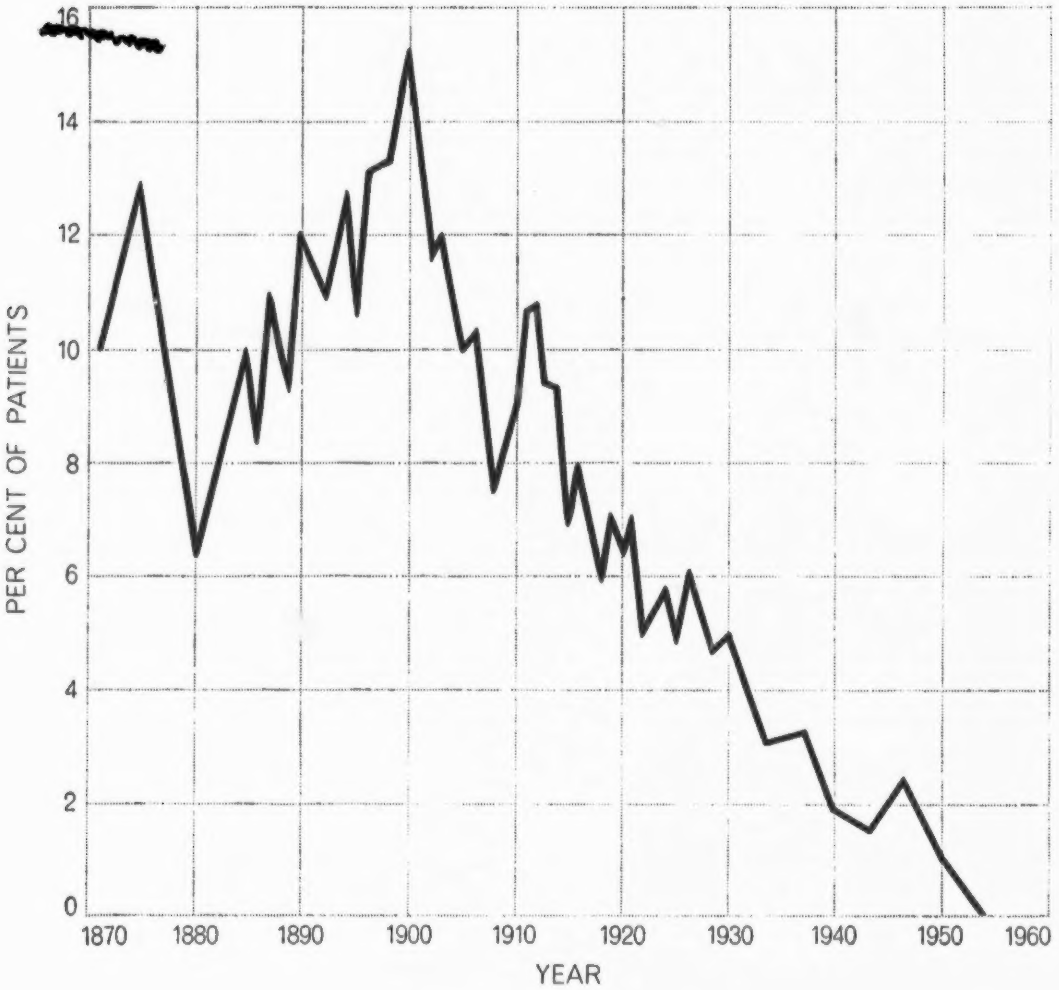


*Infected cells (granular areas) of chick embryo are seen in this section of yolk sac. Trachoma agents produce the grainy appearance. Magnification is about 1,700 diameters.*

*Trachoma infection of cultures of human cancer cells has also been achieved in the laboratory. The large ovoid is a cell nucleus; the small round spots, inclusion bodies.*

to the agent than unvaccinated controls. J. Thomas Grayston and his co-workers in a medical research unit of the U.S. Navy in Taiwan applied a post-infection vaccination to six volunteers. All six were experimentally infected in one eye with the live agent; two months later three of the six were given an intramuscular injection of the formalin-inactivated organism, whereas the other three received only a placebo injection. In the latter group the trachoma progressed and eventually involved both eyes; in the vaccinated group it remained limited to the one eye originally infected.

Along with trachoma, a somewhat similar infection known as "swimming pool conjunctivitis" has been clarified in recent years as a by-product of the trachoma investigations. As its name suggests, it is not particularly a disease of underdeveloped areas or of populations with a low standard of living; it is most commonly picked up in contaminated swimming pools. The infectious organism is sometimes present in the genitourinary tract (as the trachoma agent never is) and is passed on from mothers to newborn babies in that way. The disease is quite different from trachoma. It produces no scars or blindness and is self-limited and self-healing. And yet this conjunctivitis, technically called inclusion blennorrhea, turns out to be caused by an agent remarkably like that of trachoma. The Lister Institute workers, who first isolated this organism,



*Decrease of trachoma in Finland accompanied advent of modern sanitation and better standard of living. Vertical scale represents percent of patients at the Helsinki Ophthalmologic Clinic treated for trachoma. Disease disappeared from Finland in the 1950's.*

have found that under certain experimental circumstances it can produce trachoma and that it is neutralized by trachoma antibodies! How two agents so closely related to each other can behave so differently in their effects on the host is a question that is currently fascinating virologists.

The investigation of trachoma has now reached an exciting stage. Several field trials of vaccines are under way in areas where the disease is prevalent. The Harvard School of Public Health is conducting such trials among American Indian school children and among infants in Saudi Arabia. Grayston's group in Taiwan has found, in the first year of a program of vaccinating preschool children with formalin-inactivated material, that the rate of trachoma infection among these children is only half to a third that among the unvaccinated. It remains to be seen how long-lasting the immunity will be and how effective such programs can be in immunizing large and differing populations. So far all that can be said is that the outlook is not discouraging.

Meanwhile it should be remembered that trachoma is essentially a disease of poverty, overcrowding and ignorance. Wherever living conditions improve, the prevalence of the infection declines dramatically. A good case in point is Finland. At the beginning of this century the Finnish people had one of the highest rates of trachoma in Europe. Thanks to their industry and elevation of their living conditions, they eliminated the disease as a problem long before any effective medical treatment became available. The 500 million trachoma sufferers who remain in the world are a vivid reminder of the opportunities that lie ahead for the application of science and technology.

# LEARNING EYE FIXATION WITHOUT VISUAL FEEDBACK

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This experiment is designed to determine if a blind person can learn to direct his gaze at a sound source.

Two questions arise in the consideration of training a blind person to fixate his eyes: *(1)* Is it necessary that skills in fixation be acquired by a certain age in order for these skills to develop fully? *(2)* Is visual feedback necessary for eye fixation? The answer to the first question seems to have been found. People of various age groups who have been blind since birth because of cataracts become able to control their eye movements after cataract removal. Certainly, blindness does not permanently impair one's ability to control eye movements, and if the postoperative improvement is due to learning, these cases indicate that there is no certain age by which eye movements must be learned. Of course, this establishing of ocular control took place after visual feedback had been made possible. This study will attempt to determine whether visual feedback is a prerequisite for learning ocular responses to stimuli. No reports have been found relating to this problem.

The eye movements of the blind relate to a social handicap of the blind and are of interest for that reason. It is commonly observed that the blind tend to have "poker faces." Dumas (1932) has shown that blind children have a limited repertoire of facial expressions. This lack of expressiveness, combined with the inability to direct the gaze at another person, limits a blind person's communication of feelings and ideas. He typically does not, through facial expression, encourage another person to speak, show disapproval or disapproval, enjoyment or annoyance, understanding or perplexity. A preliminary unpublished study by Valerie Ackerland has shown that there are specific sequences of eye movements correlated with facial expressions and that without these the expressions appear fake. Therefore, eye movement should be taught to the blind person along with facial expressions in order for the latter to convey their intended meanings and so another will attend to the content of the communication rather than its mode.

In order for a blind person to give the impression to another person that he is looking at that person he must be able to localize the sound of the other's voice and then to direct his apparent line of visual regard through the use of this information. This direction of the "gaze" should be controlled with enough precision so that the deviation of the apparent

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direction of the gaze from what would be a sighted person's line of regard would be small enough to go unnoticed by the person being looked at. It is not known if a blind person can thus direct his eyes to a source of sound with enough precision to give the impression of looking at another person.

Various studies of the precision of the localization of sound, as cited by Fisher (1964), have yielded JND's varying from 1 to 12 deg. Standing in comparison, the measurement of the precision of a judge's estimate of whether another person is looking at him has given a JND of 2.8 deg, as reported by Gibson and Pick (1963). These results allow the possibility that a blind person's accuracy in directing his gaze at sounds could be greater than another person's accuracy in determining whether the blind person is looking at him. It is encouraging to note that accuracy of localization of sound improves in environments that are less like laboratory situations and that are more like everyday situations where there are richer auditory contexts (Fisher, 1964). Thus, in environments in which most social interactions take place, the accuracy of sound localization may be at the lower end of the range of estimates obtained from varied laboratory conditions. Further, it is possible that if the gaze of a blind person is crude, this crudity will go unnoticed when it appears as a part of a total that includes the appropriate timing of the gaze in response to the words of the other person and in a customary relationship to the other facial expressions. The impression may be one of a gestalt in which any inaccuracy of the gaze is overlooked because, as with many other perceptions, there is a "closure" that fills in variations from a perfect form.

A pilot study was performed to determine whether a normal person could learn to fixate his eyes without visual feedback. Since a sighted person has had a great deal of practice in orienting his eyes toward a sound, letters of the alphabet spoken by the *E* were used to indicate the desired direction of the gaze. Positive results prompted the present study using a blind *S*.

## Subject

The *S* was a 45-year-old male college graduate. He was blind until 3 years of age at which time cataracts were removed; after this his sight was good. Glaucoma was evidenced at 19 and led to total blindness at 25. His right eye is artificial, with some muscles attached. He has no other known handicaps.

## Apparatus

For observing eye movements an infrared detection device was used, a military "Sniperscope, Set No. 1." A lens for bringing into focus on the viewing screen a 12-in. area at a distance of 4 ft, and an infrared filter which eliminated a faint light emitted by the scope, were mounted, along with the scope, on an optical bench. A chin rest was used to aid the *S* in keeping his head stationary. A piece of plastic on which lines were scratched was used to judge the degree of rotation of the left eye; the plastic was inserted in place of a left lens in eyeglass frames. The location of these lines was set by finding the point at which the center of the pupil was located when a person was looking straight ahead; then a piece of thread was attached at this point on the plastic and a needle was attached to the other end of the thread. The needle was then moved 10 deg at a time, as was indicated by a protractor held against the glasses, and the person was directed to look at the needle. The location of the center of the pupil was marked on the glasses for each of the positions.

The stimuli were sounds produced by nine relays (Cook No. MS 24245-1) wired as buzzers. They were placed in a straight line facing the *S*. They were spaced 10 deg apart using the chin rest as the vertex. The center buzzer was 4 ft directly in front of the *S*, slightly above eye level. Their tone, range, and intensity were roughly similar to the human voice and the duration of the stimulus was 2 sec. A paper tape recording typewriter was used to record the responses.

## Procedure

The purpose of the experiment was explained to the *S*. The *S* was seated at a table with his chin in the chin rest. The room was totally dark. The *S* put on the glasses and received his instructions. Two buzzers were presented randomly at 7-sec intervals. The outside buzzers were presented first because this crude movement of the eye would be a basis for training on the finer discriminations necessary to locate the other buzzers. The other buzzers were added to the series in random order.

During the first session the right eye was used. After that the left eye was used because the muscles of that eye had not been operated on as was the case with the right eye.

Because at first there was no movement, or very little movement, the *S* was informed of his progress simply by being praised when he moved his eye at all and by occasionally being told to try to move it a little further. The *S* was moving his eye enough by the third session to inform him if his line of gaze was correct and if not, the degree of his error by a number, spoken by the *E*, which represented the number of 10-deg-units the gaze deviated in the horizontal plane from the correct position. The *S* was instructed to maintain the direction of gaze until the next stimulus was presented. At the same time the buzzer at which the *S* was looking was recorded.

A new buzzer was added to the stimulus series each time the *S* reached a criterion of 10 errorless trials unless this occurred near the end of a session, in which case the new stimulus was added after the criterion was again reached during the next session. Rest periods of 1 to 3 min were given whenever the *S* reported he was tired and at the end of a series of 30 trials. The sessions lasted no longer than 1 hr. The experiment was continued until evidence was obtained which indicated that orientation of the eyes toward a sound, in a blind *S*, is possible.

## Results

The *S*'s progress is shown in Figure 1. The mean degree of deviation, within blocks of five trials, is presented for each stimulus. After a few trials the *S* began to move his eyes and gradually extended their range of movement. When a new stimulus was added, the *S*'s learning was more rapid than it had been with the preceding stimuli. Also, the introduction of the new stimulus appeared to have a temporary detrimental effect on the accuracy of response to the other stimuli.

To determine whether the *S*'s responses were accurate enough to give a person the impression of being looked at, an assistant stood behind the buzzers and talked to the *S*, then he walked from one buzzer to another while talking. The assistant reported that it did appear as though the *S* was directing his gaze at him and that it appeared that the *S* followed his movements.

## Discussion

This study indicates that it is possible to train a blind person to direct his gaze at a sound source in the horizontal dimension. The present study does not reveal what type of processes are involved in this learning. The results have some of the characteristics which appear in rote learning. Proactive facilitation appeared to be operating since responses to new stimuli were learned more rapidly than had those to the previous stimuli. Also the introduction of these new stimuli tended to produce a decrement in the response accuracy to the other stimuli. This phenomenon is similar to the retroactive inhibition usually encountered in rote learning. However, spatial concepts may be inherently involved and set this learning apart from classical categories of learning.

Finally, it should be pointed out that it is not possible to generalize the results of this study to the congenitally blind--indeed, it is not even known yet if this capacity to

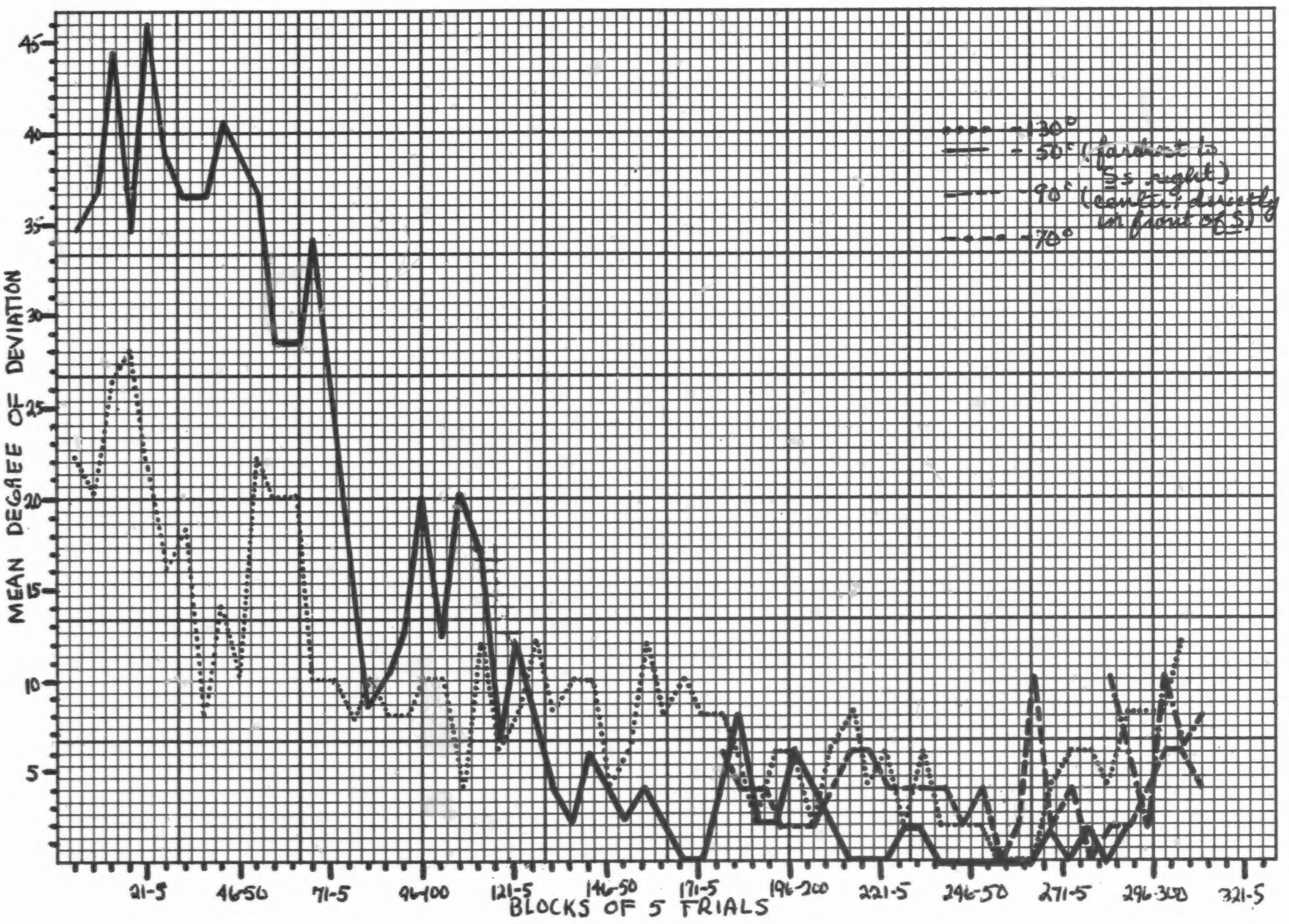

Figure 1. S's Progress

learn such eye movement requires some level of intelligence or a certain age. The effects of age and intelligence on this learning as well as the possibility of learning control of eye movements in the vertical dimension are problems which must be pursued in another study.

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# THE EFFECT OF SIGNAL STRENGTH ON REACTION TIMES TO AUDITORY SIGNALS IN NOISE*

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Many of the studies that seek to link variations in reaction time with variations in the intensity of an auditory signal are reviewed in Chocholle's reports of his own very thorough investigations (1945, 1963). His conclusions are frequently mentioned throughout this paper.

If any justification is needed for studying the relationship of reaction time and intensity of auditory signal yet again, it may perhaps be sought in three ways. First, we wished to include in this study a number of blind people, whose performance could be compared with that of sighted *S*s. Second, we intended so to design the experimental procedure as to move further from the "signal known exactly" situation as discussed by Green, Birdsall, and Tanner (1957). (Chocholle presented the same signal twenty times in succession.) Third, we were affected by the advent of the theory of signal detectability, as outlined, for example, by Swets (1961). It is a basic assumption of this theory that in any experiment involving signal detection some amount of random "noise" is always present, ranging from unwanted noise produced by the experimental apparatus or in the general environment to spontaneous neural activity. To counteract any effect this may have on the results, it is considered essential to add background noise to bring the noise up to measurable levels, where due allowance can be made for its influence. (Chocholle does, as a matter of interest, mention unwanted noise from apparatus and from road traffic during his investigation but claims to show that these did not affect the results.)

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*Completed February, 1967.

*The project was financed by the Medical Research Council, and a grant was also received from the Pantke-Giebler Foundation of America. Advice and comment from Professor B. M. Foss, of the Institute of Education, London, were of the utmost value throughout the project. Assistance was also received from Dr. J. A. Leonard, of the Department of Psychology, University of Nottingham, particularly on matters of equipment. Special apparatus was designed and built in the workshops of the M. R. C. Applied Psychology Research Unit at Cambridge, and for this I am gratefully indebted to Dr. D. E. Broadbent and several members of his staff. To all of these, and to so many others, too numerous to list here, I wish to profer my thanks.*

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The aim of the present investigation, incorporating this technique, was simply to look again at the relationship between signal strength and reaction time, in the new situation, with particular reference to signals of around threshold intensity. It was also thought that the results might have some relevance to the design of auditory outputs from the kinds of "travel aid" for the blind currently being evaluated. Although these outputs are not in themselves intensity-modulated, variations in signal intensity are a marked feature of the displays and should perhaps be given more serious consideration if they are found to have a strong influence on reaction times. This aspect of the investigation is discussed at some length in the introductory remarks to the main experiment: "A comparison of the reaction times of blind and sighted subjects. . . . "

Due to a generous extension of the project by the Medical Research Council, we were able to carry out a brief investigation of the effect of varying signal frequency upon reaction time.

In the present study the first experiment is concerned with finding appropriate working levels, of signal and noise, and testing the experimental procedure. In the second, third, and fourth, the range of signals is further explored, first upwards then downwards to and beyond threshold, while signal latency, warning signal, possible serial position effects of the signal, and total duration of experimental sessions are also looked at. In a sense, these all lead up to the fifth "main" experiment, in which blind and sighted *S*s are compared. The final experiment is again more or less exploratory, dealing this time with signal frequency.

## Apparatus

The tones used throughout were sine waves produced by an Advance Signal Generator Type H.l. "White noise" was produced by a zener diode. Both of these were fed to a purpose-built piece of apparatus which enabled signal intensity and noise intensity to be separately controlled, the temporal location of the signal within the duration of the noise to be preset, and selection of the type of warning signal. This could be a click, a tone of equal frequency and intensity to the signal, or a tone of the same frequency but fixed intensity. The output from this was to headphones, binaurally in phase (Canadian ex-government stock, make unknown). The occurrence of the signal started a Dekatron timer which the subject stopped when he depressed the response key, a standard Morse key. The adaptation of the timer to a tactual read-out, for a blind operator, is described by Leonard and Davidson (1965). The apparatus also incorporated a buzzer activated by responses being made in anticipation of the signal. In actual fact, these proved to be so very few that this precaution was scarcely necessary. The *S* sat at a table in a small adjoining soundproof cubicle.

Measurements of both signal and noise output were made at the headphones, using the flat-plate coupler supplied with the Bruel and Kjaer artificial ear, Type 4154, in conjunction with a Bruel and Kjaer Frequency Analyser, Type 2107. First, considering the output of the tone at 1,000 hz, Table 1 and Figure 1 give the sound pressures for each of the headphones for various indicated applied voltages. Table 2 and Figure 2 give the octave band analysis of the noise from each of the headphones. From these data it is obvious that one headphone is somewhat more sensitive than the other, particularly in the region of 1,000 hz, so that there will be a tendency for one ear to dominate. In view of this, it is probably better to use only the data for the more sensitive headphone. The octave band analysis reveals a gently rising spectrum level which is fairly smooth over the range 250 to 8,000 hz. In specifying the character of the noise, one may use the results shown in

**Table 1**

**Sound Pressure Level of 1,000 hz Tone**

|  | *Db re 0.0002 dyn/cm$^2$* |  |
|---|---|---|
| Applied Voltage | Earphone No. 1 | Earphone No. 2 |
| 0.001 | .. | 31.0 |
| 0.002 | .. | 37.0 |
| 0.004 | 34.0 | 43.0 |
| 0.010 | .. | 52.9 |
| 0.020 | .. | 58.9 |
| 0.040 | .. | 64.9 |
| 0.100 | .. | 73.0 |
| 0.200 | .. | 78.9 |
| 0.400 | .. | 84.8 |

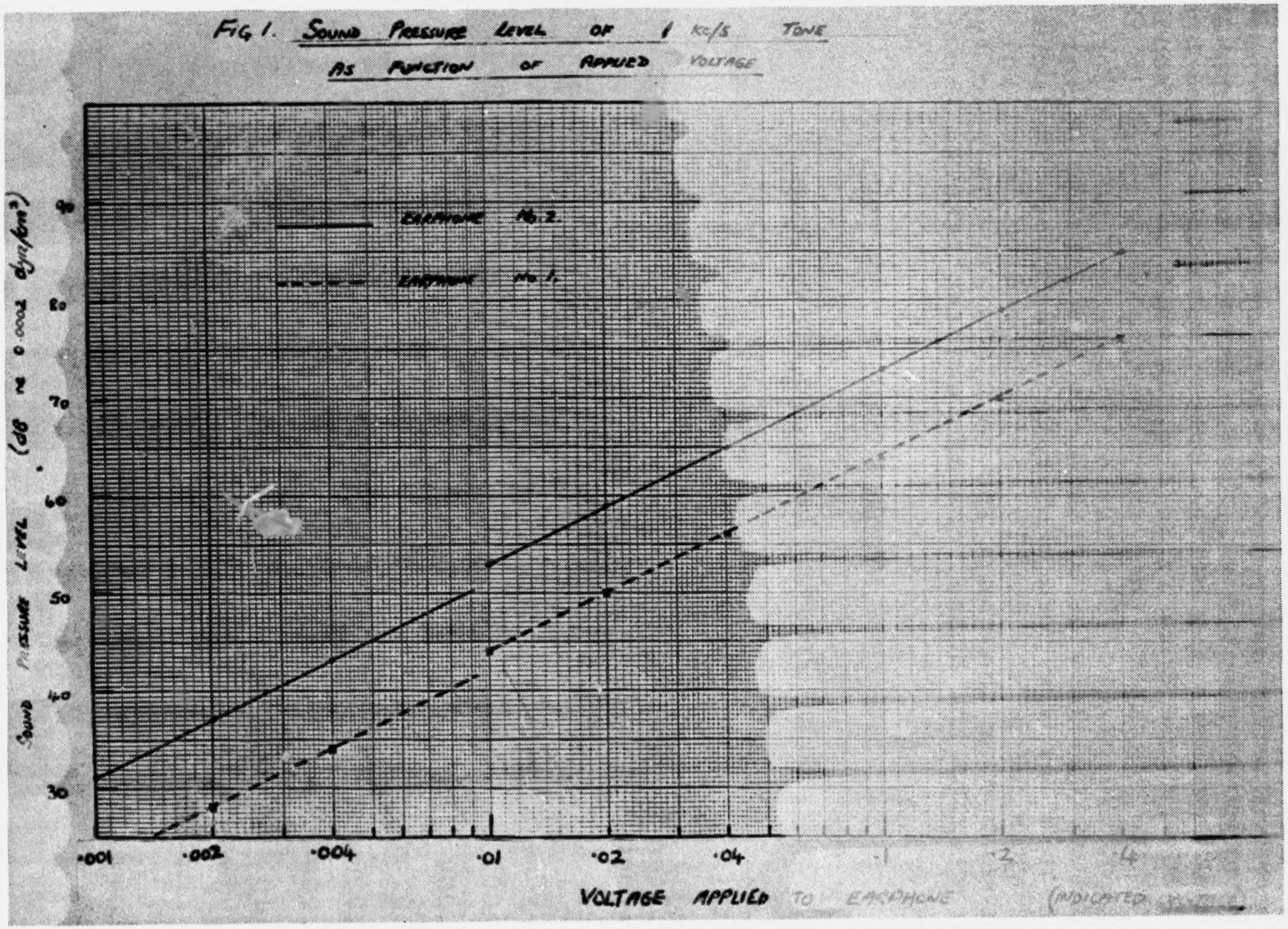


Figure 1. Sound Pressure Level of 1 kc/s Tone As Function of Applied Voltage

## Table 2

### Band Pressure Levels for 0.05 Volts Noise Output (db)

| *Center Frequency of Octave Band* | *Earphone No. 1* | *Earphone No. 2* |
|---|---|---|
| 250 | 35.0 | 51.5 |
| 500 | 44.0 | 57.0 |
| 1,000 | 47.0 | 56.0 |
| 2,000 | 41.5 | 50.5 |
| 4,000 | 60.5 | 61.0 |
| 8,000 | 61.0 | 63.0 |

Figure 2, but in addition one could also quote the loudness level, this being the sound pressure level of a 1,000 hz tone which would, on average, be judged equally loud as the noise in question. Figure 3 enables one to read the loudness level in phons as a function of the indicated noise voltage. However, this is not very rigorous, since the method used for calculating loudness (Stevens Mark VI, as specified in Draft I.S.O. Recommendation No. 675) is strictly applicable to free-field binaural listening only, and in this case probably over-estimates the true loudness by quite a large margin, up to 8 phons. However, the loudness is determined primarily by the level in the 4,000 and 8,000 hz bands, and therefore is not of great interest here, where concern is mainly with the masking effect of the noise on the 1,000 hz signal. The noise spectrum is substantially flat in the region of 1,000 hz. This was checked against published masking curves, and it is evident that the only portion of the noise spectrum that will mask the tone is that in a "critical band" centered on 1,000 hz; the noise level at lower frequencies is insufficient to contribute to masking. A critical band at this frequency is about one-third octave wide, so the level in the relevant critical band can be obtained from the band level in the octave centered on 1,000 hz by subtracting 5 db from the latter. Taking as a concrete example headphone 2 with a noise voltage of 0.05 v, the octave band level is 56 db (Table 2), so the critical band level is approximately 51 db, and this is the level corresponding to a tone signal. A 1,000 hz tone having a level of some 6 to 9 db below this is commonly found to be still just

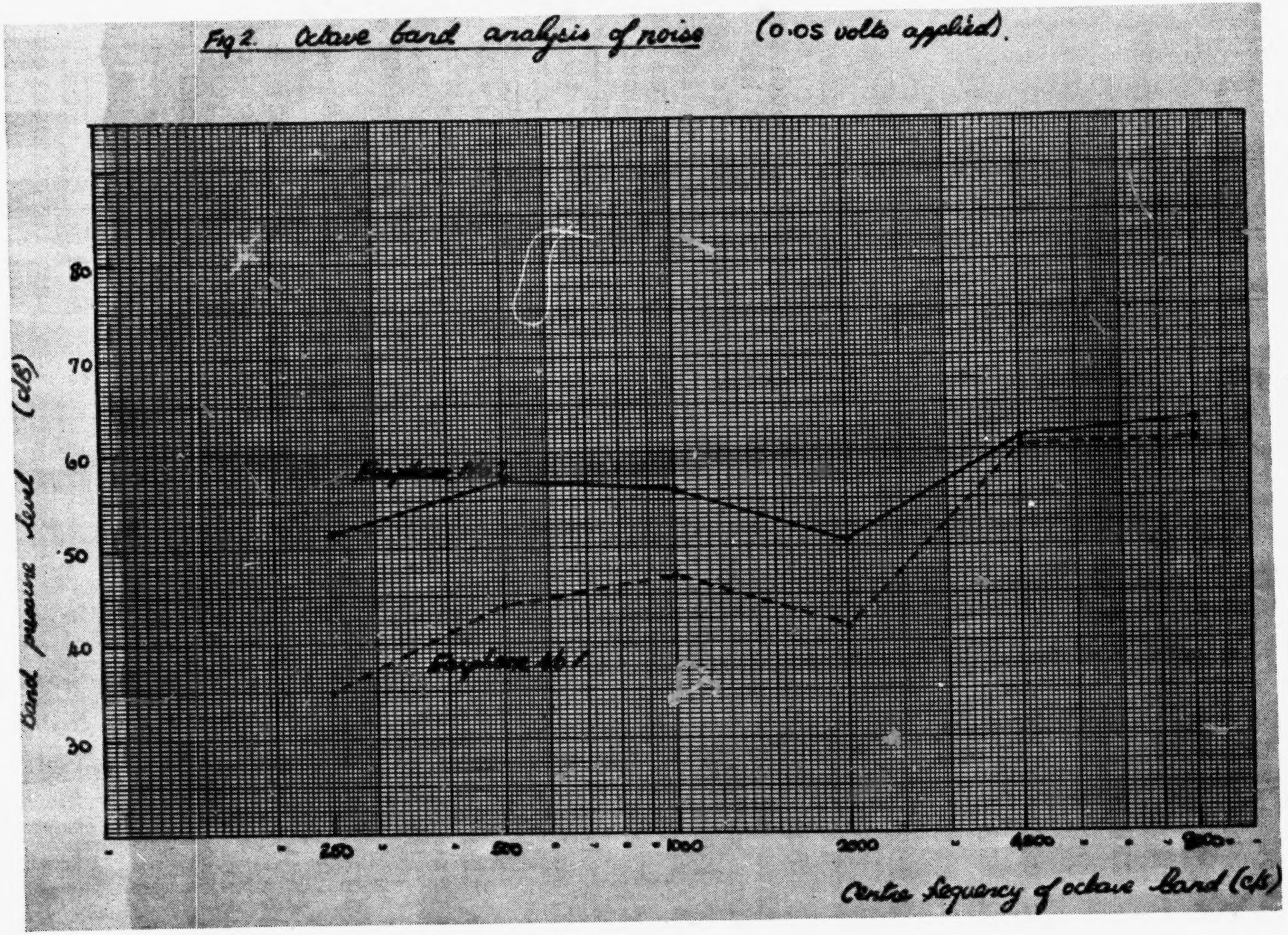


*Figure 2. Octave Band Analysis of Noise (0.05 v Applied)*

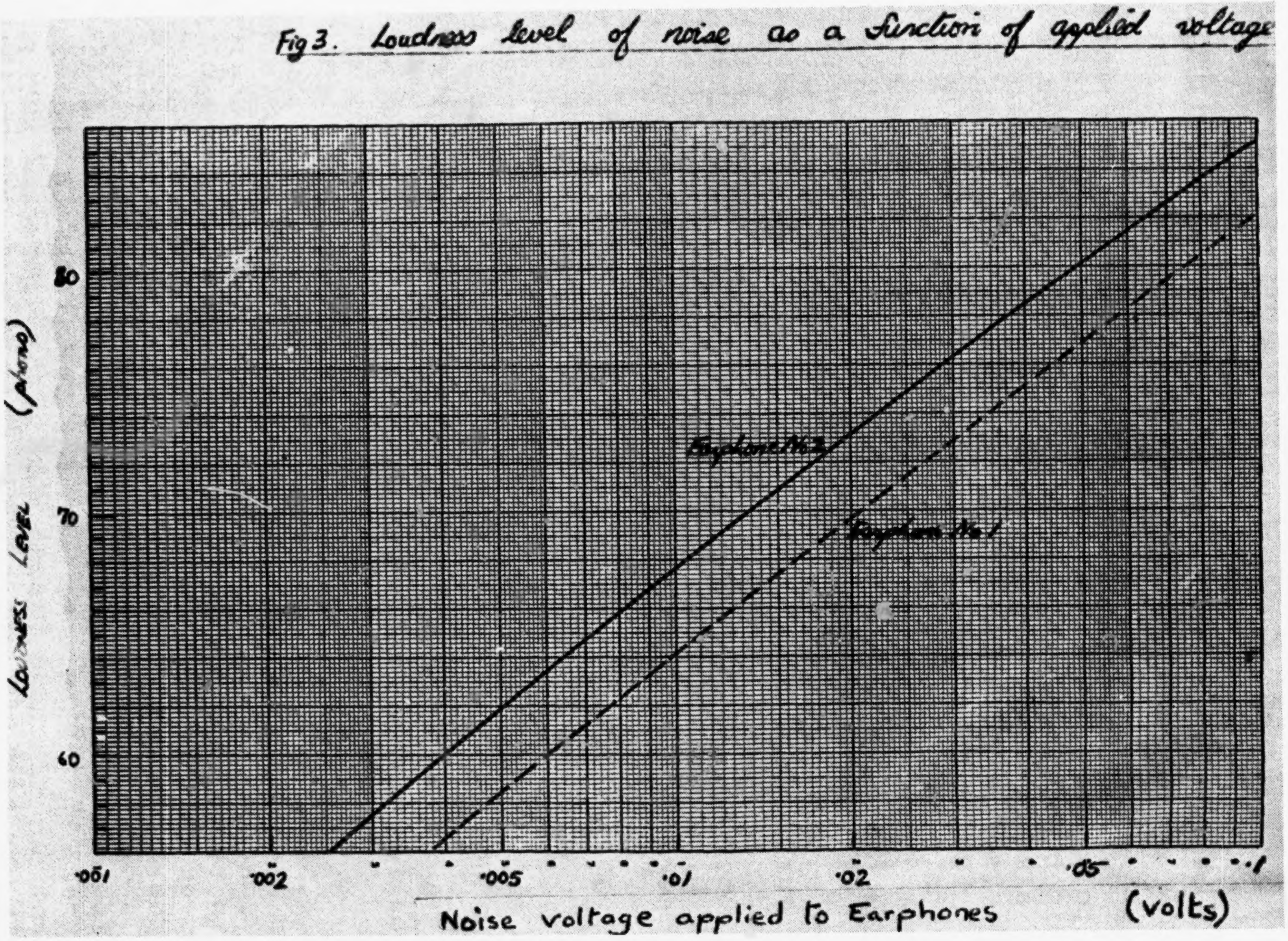


Figure 3. Loudness Level of Noise As a Function of Applied Voltage

audible, because the total loudness is increased when both signal and noise are heard together. In the third and fourth experiments to be reported, response rates were high to signals of a level 14 db below that of the noise. This finding is, however, not borne out by other results, and should perhaps be regarded with some suspicion, although worth while recording.

## ESTABLISHING WORKING LEVELS FOR SIGNALS AND NOISE AND TESTING EXPERIMENTAL PROCEDURE

The first experiment was simply aimed at exploring reactions to a range of signal intensities, to find realistic and convenient working levels of signal and noise for future use. It was also desired to test the experimental procedure that had been devised and to observe any effects of fatigue on the *S*s, so that future experimental sessions might be adjusted to approximately the correct length to avoid such effects. The underlying hypothesis was that when reaction times were compared for various signal strengths one would find a decrease of time with each increase in signal intensity over the range of intensities looked at.

Four *S*s were used in this preliminary exploration: three male and one female, students from the Psychology Department of Birkbeck College. Their ages were 20, 30, 30, and 34. The four *S*s were not selected in any way, but were simply the first "volunteers." A rather low level of white noise was used (0.005 v, 31 db), with eight intensities of signal to be detected against this, ranging from 0.008 v (2 db below to 40 db above the masking level of the noise) to 0.08 v. The signal consisted of a burst of tone, varying in its intensity, but always of a frequency of 1,000 hz, and always of a duration of 0.1 sec. An exactly similar tone served as a warning signal, 0.3 sec before the onset of the white noise. The noise itself lasted for 6 sec, and the location of the signal within this duration was varied, to avoid any risk of the *S* becoming accustomed to responding after a fixed interval from either warning signal or onset of noise. Thus, the signal might occur 0.2, 1.4, 2.6, 3.8, or 5.0 sec after the onset of noise. Forty signals were thus presented, differing in intensity, in temporal location, or in both. Each signal was presented four times in the course of the experiment, making a total of twenty signals at each of the eight intensities, for each *S*.

The *S* was seated before a table in the soundproof cubicle; he was shown how to adjust the headphones for comfort and how to manipulate the response key. It was pointed out that the "preferred" hand should be used for this task and that it was important not to change hands during the course of the experiment (it was perhaps just as well that in the event all the *S*s, in this and the subsequent experiments, turned out to be right-handed, so that this potential source of variability can presumably be forgotten). The *S* then heard a sample of the noise and of the tone, so that he "knew what we were talking about." It was explained that in the experiment he would first hear a warning signal, "a pip, rather like the Greenwich time signals on the radio," but that he need not do anything about this other than "get ready." This would be followed "almost immediately" by several seconds of the noise he had just heard, and somewhere in this noise ". . . it may be just about straightaway or not until after several seconds. . . " would be the same tone he had heard as a warning signal. It was explained that this "signal" would vary in its "loudness," and that his job was simply to press the key as quickly as possible if he heard, or thought he heard, the signal. A number of "trial runs" were then gone through in which any misunderstandings could be spotted and corrected. The number of these trial runs was not fixed, they were continued until it seemed to the *E* that the *S* had settled into the procedure and his results had ceased to show the kind of wild variability characteristic of the initial responses. In the experiment proper the signals fell into batches of five, a given intensity being presented at the five different temporal intervals, then on to another intensity. This was rendered necessary by the procedure adopted for manually recording the results in braille. The intensities were varied according to a prearranged "random" order. When 80 responses had been obtained the *S* went away for approximately half an hour's break before completing a further 80 responses, preceded as before by trial runs.

The raw data, the time taken to react to each signal measured to the nearest hundredth of a second, were reduced to more manageable proportions when the times representing the four repetitions of each signal were totalled and an average time produced. This time represented the average for that signal intensity, with that interval after onset of noise, for that particular *S*. These results were then submitted to an analysis of variance.

Two of the four *S*s give results supporting the original hypothesis; their reactions do become faster as signal intensity is increased. With the third *S* this state of affairs holds good over the three lowest signal intensities used, but above that level there seems little systematic relationship between speed of reaction and intensity of signal. As to the fourth *S*, one can say no more than that the slowest reactions occur to the lowest intensity. Not surprisingly, the analysis showed statistically significant interactions between *S*s and intensities, *S*s and "times" (the various intervals used between onset of noise and signal), and "times" and intensities. The reactions of all four *S*s were slowest when the interval was down to 0.2 sec, three of them find the longest, 5.0-sec, interval the next slowest, with the 0.4-sec interval somewhat quicker. Two of the *S*s respond fastest at the 2.6-sec interval; the remaining two are at their fastest with the 3.6-sec interval. It is very noticeable that when "times" (intervals) and intensities are taken together, it is these 2.6-sec and 3.8-sec results that show a straightforward relation between speed of reaction and intensity of signal, while at the other "times" the higher intensities are often responded to more slowly than are weaker signals. The 0.2-interval always goes with the slowest reactions, whatever the intensity. These results are broadly compatible with Klemmer's finding (1956) that the phenomena of "adaptation level" applies to length of foreperiod.

These three, rather unclear, interactions make it not possible to go on and sort out the effect of single factors on the results. It seems obvious from inspecting these, however, that the biggest single source of variation in the reaction times is the "between *S*" difference. The total results of the fastest *S* represent only 68 percent of the total time taken by the slowest *S*. The totals for the different signal intensities show a steady decrease (as reaction becomes quicker) with rising intensity except that the third highest intensity, 0.02 v (28 db), is inexplicably faster than any other. This curious finding emerged again in later experiments, where it will be treated at greater length.

It seemed clear that the experimental procedure was suited to its purpose. It also seemed that though there was some general support for the underlying hypothesis the picture was, as hinted at above, decidedly complicated by factors other than signal intensity. Experience had now suggested that the experiment as now planned was apt to be too long and fatiguing for the *S*, and that the levels of signal and noise which had been used were, in general, too weak.

## EXPLORING A HIGHER INTENSITY RANGE

The first exploratory experiment had been altogether too "quiet," and rather too long. It had shown, however, that the procedure was basically satisfactory and that variation of reaction time linked to signal intensity did occur, although other factors came into play and made the picture complicated. A slightly shorter experiment was therefore designed using higher intensities of both signal and noise.

The *S*s were six evening class students attending a course in Psychology at Morley College, four males and two females. Regarding age, they fell neatly into two groups, three clustering around 30, the other three in their early 50's.

### Analysis of Variance

| *Source* | *SS* | *df* | *Variance* |
|---|---|---|---|
| Intensity | 2,276.59 | 7 | 320.65 |
| "Times" | 1,372.41 | 4 | 343.1 |
| Subjects | 3,949.90 | 3 | 1,316.63 |
| Interactions | | | |
| Intensity/times | 691.29 | 28 | 24.69 |
| Subjects/times | 459.67 | 12 | 38.31 |
| Subjects/intensity | 361.88 | 21 | 17.23 |
| Residual | 745.42 | 84 | 8.87 |
| Total variation | 9,857.16 | 159 | |

| F ratios | | |
|---|---|---|
| Interactions | | |
| Subjects/intensity | 1.94 | Beyond 2.5 percent level |
| Subjects/times | 4.32 | Beyond 0.1 percent level |
| Intensity/times | 2.78 | Beyond 0.1 percent level |

The procedure was precisely as in the earlier experiment, with explanation, trial runs, and rest break. The same 5 "times" had been retained, 4 repetitions were obtained, but this time the experiment yielded 20 signals at each of 6 intensities (not 8), for each *S*. The noise level was stepped up to 0.05 v (51 db), with the six signal intensities ranging from 0.005 v (6 db below to 36 db above the masking level of the noise) to 0.5 v. It will be realized, of course, that as the noise level has been increased as well as the signal intensity, we are not dealing with a higher range of signal strength relative to the background noise, but with levels of both which are higher in absolute terms. In fact, the range of signal strengths is "slipped down" somewhat, compared with the previous experiment, despite the increases in absolute intensities. It was expected that the scaling-up would also make the experiment less fatiguing.

As before, the raw data were treated so as to yield an average reaction time in hundredths of a second for each *S* at each intensity and each time interval. These were then treated by analysis of variance.

Also as before, the same three interactions proved statistically significant, *S*s and intensity, *S*s and "times," and "times" and intensities. Five of the six *S*s showed, with some irregularities here and there, an apparent tendency to react more quickly as signal strength was increased; the sixth did not. Indeed, if one looks at total scores for the six intensities for this sixth *S* alone one finds the intensity yielding fastest reactions is that third from the top, just below that yielding slowest reactions! The picture with regard to "times" is the same as in the earlier experiment. The slowest reactions are with the 0.2-sec interval, next slowest the 5.0 sec, followed closely by the 1.4 sec, with nothing to guide a choice between the remaining two. So one would be justified in saying that 9 out of 10 *S*s, so far, agree on this ordering of the time intervals. The only surprising thing in this, in my own opinion, is that the 3.8 sec, which is when all is said and done very nearly 4 whole sec, should be as fast as it is; and that the 1.4-sec delay should yield inferior results. As to "times" and intensity, the 5.0-sec interval is the only one in which the reaction times show a definite progressive decrease as intensity is raised; at all other intervals "reversals" occur, that is, one intensity is responded to more quickly than another, weaker, intensity. It may be worth mentioning, in view of later findings, that it is the 0.1 (22 db) and 0.02 (8 db) signal intensities which seem to evoke an unusually fast response. This finding does not accord with that in the earlier investigation, where it was not the 5.0-sec interval, but the 2.6- and 3.8-sec intervals which showed clear relationships between intensity and reaction time. The interactions are too "fuzzy" to allow of any satisfactory explanations.

Again, it is obvious enough from inspection of the data that the greatest single source of variability are the differences between *S*s. The over-all performance of three of the *S*s seems fairly comparable, giving a mean reaction time of about 280 ms, whereas the remaining three give means of 378, 410 and 484 ms. Nor is this a division by age, since two of the older (male) *S*s come into the former group. It is rather curious that although there is a general relationship between signal strength and speed of reaction, this relationship is not at all precise. The main disturbance centers about the two levels of signal intensity which were second and third from the top of the range explored. It is difficult to say whether the third (the lower) intensity is being reacted to with unexpected swiftness, or that the intensity above this is reacted to very slowly, or something of both. What is striking, however, is that this is exactly the ordinal position on the intensity scale in which such disturbances were most common in the first experiment, although this does not represent the same signal-to-noise ratio.

### Analysis of Variance

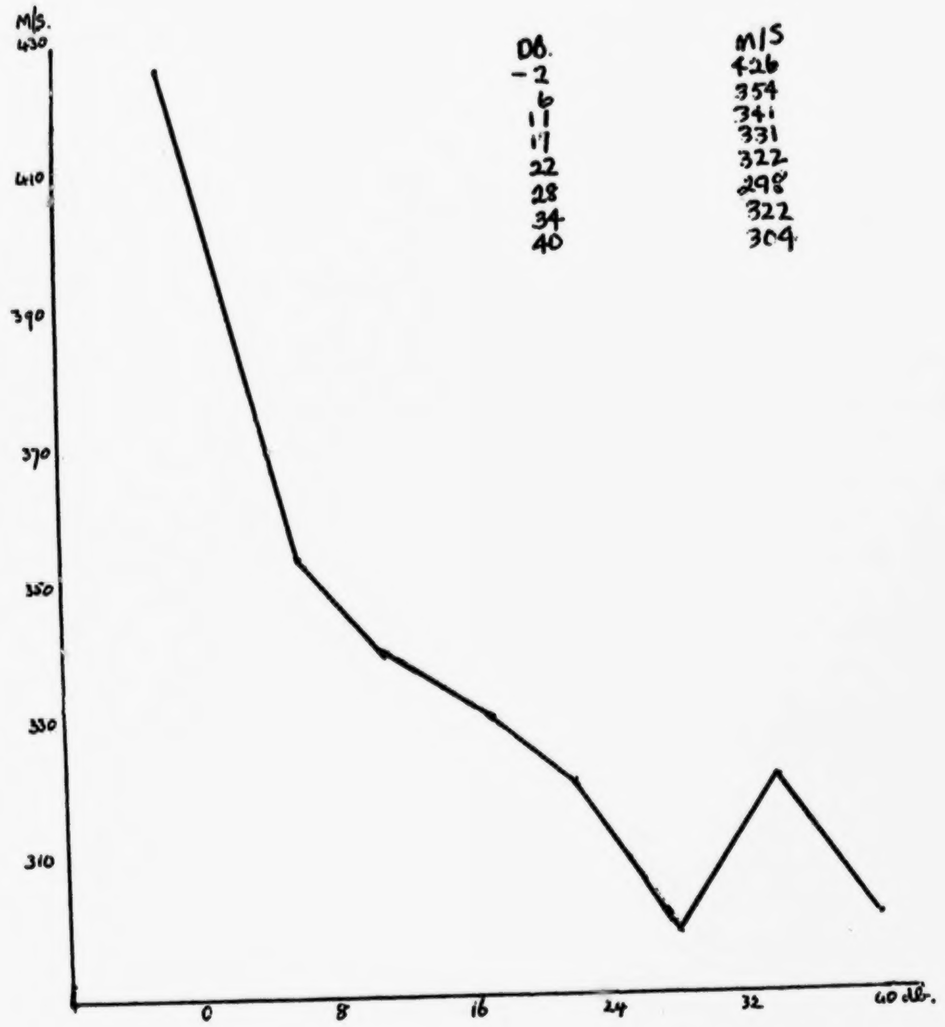
| *Source* | *SS* | *df* | *Variance* |
|---|---|---|---|
| Intensity | 6,093.20 | 5 | 1,218.64 |
| "Times" | 277.00 | 4 | 69.25 |
| Subjects | 10,580.83 | 5 | 2,116.17 |
| Interactions | | | |
| "Times"/intensity | 349.00 | 20 | 17.45 |
| "Times"/subjects | 497.74 | 20 | 24.89 |
| Subjects/intensity | 2,576.01 | 25 | 103.04 |
| Residual | 1,037.68 | 100 | 10.38 |
| Total variance | 21,411.46 | 179 | |
| F ratios | | | |
| Interactions | | | |
| "Times"/intensity | 1.68 | Beyond 5 percent level | |
| "Times"/subjects | 2.40 | Beyond 0.1 percent level | |
| Subjects/intensity | 9.93 | Beyond 0.1 percent level | |

## REACTIONS TO SIGNALS OF THRESHOLD INTENSITY

In the first experiment the lowest intensity of signal used, minus 2 db, had produced a response with a mean latency of 426 ms on no less than 95 percent of the occasions on which it was presented. For the corresponding signal in the second experiment, minus 6 db, which was of less intensity relative to the background noise, the response rate sinks to 62 percent, while the mean latency has risen to 479 ms. The third experiment was, therefore, designed to employ lower levels of signal intensity, in the expectation of investigating the region around signal/noise threshold.

Four of the six *S*s of the previous experiment were willing to give their assistance a second time: three male, one female, ages 25, 29, 35, and 53. It was hoped that by using the same people, the same experimental procedure, and some of the same intensities of signal and noise, interesting comparisons with the results of the preceding experiment would be possible. Thus, the four highest signal intensities to be used were, in fact, the four lowest of the earlier experiment, and it might be interesting to see whether reaction time to the same physical signal would show any influence from the position of that particular signal in the range of signals being used. (It may be objected that the results would be complicated by the fact that the *S*s had had previous experience in the situation. However, as an interval of 43 to 50 days separated the two experiments, this did not seem likely to be a significant factor.)

Against a level of background noise of 0.05 (51 db), 10 intensities of signal were used, ranging from 0.0008 v to 0.1 v (more than 22 db below to 22 db above the masking level of the noise), with a concentration in the region in which the threshold was predicted. To offset this large number of signal intensities, the 5-sec interval between onset of noise and the signal was omitted, leaving the 0.2-, 1.4-, 2.6-, and 3.8-sec intervals. There were four occurrences of each signal at each time delay, which would have made the experiment a little too long, except that the procedure had by now become streamlined and faster.



| DB. | M/S |
|---|---|
| -2 | 426 |
| 6 | 354 |
| 11 | 341 |
| 17 | 331 |
| 22 | 322 |
| 28 | 298 |
| 34 | 322 |
| 40 | 304 |

Even at the lowest level of signal intensity there is still one response, presumably a chance detection by the youngest, female, *S*. At the intensity immediately above this, she reacted to two signals, and the next youngest (male) *S* to three. Each of the four *S*s detects one or more signals at the following intensity of 0.001 v (-20 db) resulting in a response rate of 11 percent, with a mean latency of 489 ms. It is obvious that the threshold falls somewhere between this intensity and the one above it, 0.002 v (-14 db), which elicits a 94 percent response, with a mean latency of 439 ms. The intensity beyond this, 0.003 v (-9 db), evokes a 95 percent reaction, latency down to 378 ms, and no signals of greater intensity go undetected.

When those results are compared which come from signal/noise intensities common to this and the previous experiment, we find:

Mean Reaction Time

| Signal | 0.005<br>-6 | 0.02<br>8 | 0.05<br>16 | 0.1 v<br>22 db |
|---|---|---|---|---|
| Before | 479 | 345 | 346 | 319 |
| Now | 361 | 328 | 336 | 297 |

Breaking down the results by *S*s instead of intensity, we see that in the present experiment one *S* reacts throughout more speedily than on the earlier occasion, her reactions being on average 175 ms faster. Two more *S*s respond more quickly three quarters of the time, the latency of their reaction being reduced by 32 ms in one case and 47 ms in the other. The fourth *S*, on the other hand, is not faster but slower (64 ms slower), on the average. It is not easy to suggest why there should be this discrepancy; although it is no explanation, it should be pointed out that both in this and in the previous experiment, it is always this same *S* who is "the odd man out." In the previous experiment he was the one person whose speed of reacting showed no relationship with signal intensity, while he found optimal that time delay between onset of noise and signal which everyone else found slowest. Again, in this later experiment, the reactions of this one *S* show little relationship with signal intensity, and he has become even more divergent regarding speed of reaction. Apart from this one *S*, then, there is a general quickening of reaction to all four signal intensities now that they form, not the lower end of the range being explored, but the upper end.

It was only possible to include, in the analysis of variance, data concerning seven of the ten signal intensities, there being too few results for the three lowest to make their inclusion feasible. On this occasion there was no statistically significant interaction between *S*s and intensity or between "times" and intensity. It was therefore possible, for the first time, to examine statistically the data concerning signal intensity untainted by any known interaction. The interaction between *S*s and "times," time delay of the signal, did achieve significance, but the picture is too unclear to make it worth saying more than that different *S*s appear to respond most quickly with different delays, that is, while one thrives on the longer delays, another is at his best with the short delays. It will be remembered that to save time and fatigue the 5-sec time delay had been dropped in this experiment. This seems to have brought about a change in the ordering of the results from the remaining "times." The tendency in the first two experiments was for there to be no very great difference among the delays of 1.4 sec and longer, compared with the difference of these from the 0.2-sec delay. Now, however, with the longest delay 3.8 sec, we find that this is the "time" which apparently gives most trouble; the others, even the 0.2-sec, being noticeably faster and virtually equal. It is as if there had been a shift in the "center of gravity" of some subjective time scale, so that now the other end of the seesaw has come up.

The results do show that with minor "reversals" here and there reaction time tends to become shorter as signal intensity above background noise level is increased. If the results of the one *S* described above are omitted, the irregularities are also removed and the correspondence is straightforward. It would be misleading, however, not to point out that the four signal intensities in the middle of the suprathreshold range used do appear to be treated as more or less equivalent. There is no difference in speed between reactions to a signal of 0.02 v (8 db) and one of 0.05 v (16 db), and not very much between those results and those with signals of 0.005 or 0.004 v (-6 or -8 db).

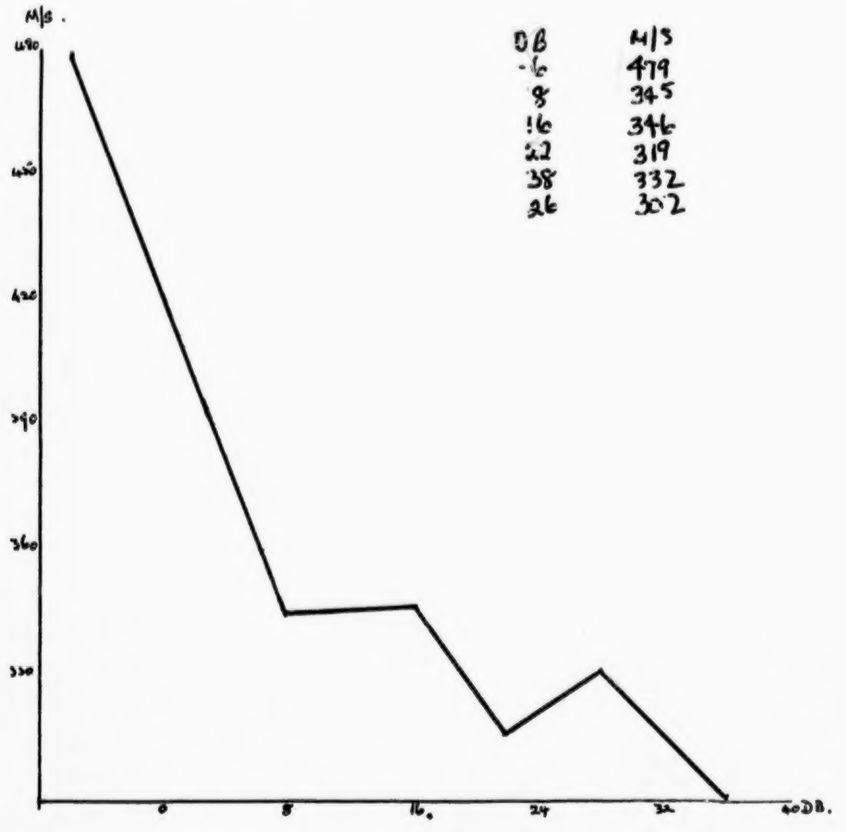
## Analysis of Variance

| *Source* | *SS* | *df* | *Variance* |
|---|---|---|---|
| Intensity | 1,978.94 | 6 | 329.82 |
| "Times" | 306.73 | 3 | 102.24 |
| Subjects | 15,835.45 | 3 | 5,278.48 |
| Interaction | | | |
| Intensity/"times" | 294.97 | 18 | 16.39 |
| Intensity/subjects | 369.47 | 18 | 20.53 |
| Subjects/"times" | 536.04 | 9 | 59.56 |
| Residual | 1,109.62 | 54 | 20.55 |
| Total variance | 20,431.22 | 111 | |

F Ratios

Interactions

| | | |
|---|---|---|
| Subjects/"times" | 2.89 | Beyond 1 percent level |
| Intensity/subjects | 1.00 | Nonsignificant |
| Intensity/"times" | 1.25 | Nonsignificant |
| Intensity | 16.05 | Beyond 0.1 percent level |



| DB | M/S |
|---|---|
| -6 | 479 |
| 8 | 345 |
| 16 | 346 |
| 22 | 319 |
| 38 | 332 |
| 26 | 302 |

## THE WARNING SIGNAL

In all the experiments so far the warning signal had been the same: a tone of the same duration, same frequency, and same intensity as the signal in the noise that followed. Of course, it could be argued that although the one tone is in all ways a replica of the other, still there is a difference due to one being present on its own and the other heard against a background of noise, so that in effect they are not of the same "heard" intensity. And yet, it seemed very reasonable to suppose that this warning signal, by not only alerting the *S* to expect onset of noise, but also giving him precise foreknowledge of the intensity of the signal to be detected, was having its own influence on the reaction times. It was decided, therefore, to compare results with three different warning signals ("conditions," for the sake of convenience).

1. "Equal": this was the warning signal as before, varying in intensity conjointly with the signal;

2. "Constant": this was again a 1,000 hz tone of same duration but of invariant intensity (72 db);

3. "Click": this was simply an electrically produced click in the earphones, of constant intensity and duration, but impossible to measure accurately.

*S*s were six female drama students, four aged 19, two aged 20. Seven intensities of signal were used, ranging from 0.0009 v to 0.5 v (21 db or more below to 36 db above the masking level of the noise)--virtually the full range of the equipment--against a background noise level of 0.05 v (51 db). The 3.8-sec time delay was dropped, leaving the 0.2, 1.4, and 2.6 sec "times." The experimental procedure was similar to that followed in the previous studies; two sessions separated by an adequate rest break and each introduced by "trial runs." The *S* was told in advance what the warning signal would be; each signal intensity was presented at each "time," intensities and "times" in random order; this was then repeated with a different warning signal, then again with the third type of warning signal. The whole was repeated a second time, in the same order, to form the second session. Thus, for each of the six *S*s there were 126 signals in all, 42 with each of the 3 "conditions" (warning signals); or 18 at each of the 7 intensities; or 42 at each of 3 time delays. The three "conditions" were given in a different order to each *S*, covering all possible orders in an effort to distribute any effects of practice or fatigue. Obviously it would have been better if each signal, of a given intensity and delay, under a given "condition," could have been presented more than twice, but to do this would have made the experiment altogether too demanding.

When the results are treated by analysis of variance it emerges that there is no statistically significant interaction among *S*s, intensities, and "times," nor among "conditions," intensities, and "times." However, that involving "conditions," *S*s, and "times" does reach criterion. There is no significant interaction among "conditions," *S*s, and intensity. Although analysis shows a relationship involving "conditions," "times," and *S*s, it is not easy to see what this relationship is. If we look at responses which were preceded by a click as the warning signal, we see that five out of the six *S*s react most quickly with the 1.4-sec time delay, followed by the 2.6-sec; and reactions are slowest with the shortest (0.2-sec) delay. It is not without interest that the exception to this pattern is the only *S* who retains the same order for the "times" under all the "conditions": 1.4 sec quickest, then 0.2 sec, and last 2.6 sec. For the same five people under the "equal" and "constant" conditions, however, there is very little consistency, the ordering of the "times" varying with *S* and condition; which no doubt gives rise to the significant interaction in the statistics. Five of the six people find the "equal" the condition under which quickest reactions are made, the sixth preferring the "click" warning signal. By "quickest reactions" here we mean reactions which are, on average, 20 to 70 ms faster than reactions with any other type of warning signal according to level of signal intensity. The superiority of the "equal" condition for all *S*s is absolute with the highest signal intensity used, 0.5 v (36 db); but with signal intensity 0.05 v (16 db), it seems to make no difference what type of warning signal is used. Why this should be so is not clear, as the differences show up both above and below this level. Although the data have been examined closely on this point, it is really not possible to adjudicate between the remaining two conditions, the "constant" and the "click."

Besides the four three-way interactions mentioned above, six two-way interactions were also calculated, involving all possible combinations of "conditions," "times," *S*s, and intensity, followed by the calculations for each of these factors on its own. Unfortunately, because of the statistical significance of the triple interaction already described, the only one of these possible sources of variance which could be legitimately tested for statistical significance was that attributable to intensity. Signal intensity, in fact, is seen to be a particularly significant factor, a result which was the more gratifying as it had not been possible to demonstrate this statistically in any of the earlier experiments, owing to the constant interaction of intensity with other factors. (It is certain that this would again have been the case had one not been precluded from testing the two-way interactions.) The reactions of all six *S*s become quicker as signal intensity is increased, with one *S* showing a minor "reversal" at one point. The signal to noise threshold appears to fall as in the preceding experiment between 0.001 v and 0.002 v (-20 and -14 db). The response to the latter was too incomplete to include in the analysis, so that only data from the four highest intensities were used. At signal strength 0.0009 v (-21 db), the response rate was 1.8 percent; at 0.001 v (-20 db), 3.7 percent; and at 0.002 v (-14 db), 87 percent; all three percentages were lower than the comparable figures of the previous study.

Another comparison of these results with earlier results suggests itself. When 5.0 sec was the longest time delay being used the fastest reactions occurred with the 3.8-sec delay. When this later became itself the longest delay period quickest responses are found with the 2.6-sec delay. Now that 2.6-sec represents the longest delay of the signal, 1.4-sec is the "time" most quickly responded to. So here again it looks very much as though the important factor linking the delay of the signal with speed of reacting to that signal is not the absolute length of this delay, but the length relative to the periods of delay being used.

Greater than the differences in reaction times attributable to levels of signal intensity, or "times" for which the signal is delayed, or type of warning signal, are the differences between one *S* and another. The following are the average reaction times, in ms, of the six *S*s. The meaningfulness of such figures may be rather limited, but the differences to which they point are nonetheless real:

264 301 347 358 407 422

[It should be recalled that these averages are based on data from the highest four intensities used, 0.005 to 0.4 v (-6 to 36 db), and that the figures would be considerably larger, though the differences would be much the same, were data from intensities around threshold also included.]

For these same intensities, minimal reaction times range from 180 to 290 ms, while the longest are from 440 to 620 ms.

To summarize, we could say that about 27 ms is added to reaction times if warning signals other than the "equal" are used. Over the four highest levels of signal intensity, differences in reaction time to the highest and the lowest are, on average for each warning signal, 47 to 80 ms. On the other hand, differences between the averages for one *S* and another can, at the extremes, be of the order of 150 ms. These figures suffer, of course, from a degree of arbitrariness inevitable where averages are drawn from a set of widely divergent data from *S*s who are not highly trained. Nevertheless, they have validity in a general way, and the proportions are instructive, bearing in mind the essential reservations.

## Analysis of Variance

| *Source* | *SS* | *df* | *Variance* |
|---|---|---|---|
| "Conditions | 365.68 | 2 | 182.84 |
| Subjects | 6,599.41 | 5 | 1,319.88 |
| Intensity | 1,351.80 | 3 | 450.60 |
| "Times" | 203.57 | 2 | 101.79 |
| Interactions | | | |
| "Times" and intensity | 119.67 | 6 | 19.95 |
| "Times" and subjects | 313.37 | 10 | 31.34 |
| "Times" and "conditions" | 153.66 | 4 | 38.42 |
| "Conditions" and subjects | 694.76 | 10 | 69.48 |
| "Conditions" and intensity | 332.76 | 6 | 55.46 |
| Subjects and intensity | 141.76 | 15 | 9.45 |
| "Conditions," subjects, and intensity | 717.41 | 30 | 23.91 |
| "Conditions," subjects, and "times" | 177.65 | 20 | 8.88 |
| "Conditions," intensity, and "times" | 120.07 | 12 | 10.01 |
| Subjects, intensity, and "times" | 375.44 | 30 | 12.52 |
| Total variance | 12,980.92 | 215 | |
| Residual | 1,313.91 | 60 | 21.90 |

F ratios

| | | |
|---|---|---|
| Residual subjects, intensity, and "times" | 1.749 | No significance |
| Residual "conditions," intensity, and "times" | 2.188 | No significance |
| Residual "conditions," subjects, and "times" | 2.466 | Beyond 2.5 percent |

This meant that ten out of the eleven remaining items could not be legitimately examined, leaving only

| | | |
|---|---|---|
| Intensity/residual | 20.575 | Beyond 0.1 percent |

# COMPARISON OF THE REACTION TIMES OF BLIND AND SIGHTED SUBJECTS TO AUDITORY SIGNALS OF VARIOUS INTENSITIES

As a result of the earlier experiments it was now possible to plan a final definitive study on a much larger scale. Half the *S*s of this experiment were to be blind so that comparisons could be drawn between their results and those of the other, sighted, *S*s. Any conclusions to which such comparisons pointed would be of value in at least two areas: *(1)* by filling a gap in our present knowledge of blind people's abilities and *(2)* by being relevant to the design of auditory outputs from "travel aids" for the blind. It was originally intended to have the blind *S*s further subdivided into two groups, so that other comparisons could be attempted: between those born blind or losing their sight at a very early age, and those becoming blind in later life. There is some evidence that the former are more concerned with reacting to auditory cues (Liddle, 1965, Appendix B). Also, if it is granted that it is reasonable to look for any differences between blind and sighted in this matter, then it must seem almost equally reasonable to take things a stage further and seek similar differences between those born blind and those becoming so after a number of years of visual experience. Unfortunately, it proved impossible in practice to be as selective as this. The number of blind people able and willing to participate in such experiments is, of course, limited. It is also not uncommon to find that those responsible for training or residential establishments for the blind are inclined to adopt a rather proprietary and defensive attitude when approached by someone seeking *S*s for some kind of "experiment." This is not perhaps altogether incomprehensible in view of the strange appearance of a few of the proposed "experiments." There are, of course, notable exceptions who welcome the research worker. I am indebted to members of the London Branch of the National Federation of the Blind for so readily adopting the latter point of view.

It may be as well, at this point, to intrude some remarks on the "travel aids" mentioned above. Quite an extensive literature already exists on this subject, and anyone wishing to know more than the barest outlines of the field could hardly do better than turn up the relevant papers from the three conferences listed under *Proceedings* in the references which conclude this report. There have been many attempts over the past twenty years to develop satisfactory "guidance devices," "mobility aids," or "travel aids" for the blind which have taken advantage of the increasing miniaturization of electronic components and circuitry. These have followed a number of patterns, but the fundamental idea seems much the same in all. The equipment, hand-held, slung in front of the chest, head- or cane-mounted, emits a beam of energy which is used, by manual or automatic scanning, to probe the environment. The beam may consist of sonic energy, within or above the human auditory range, or light, infrared, visible or ultraviolet. Energy in the UHF radio range has also been tried. Some of this energy output is reflected by the surfaces of objects in the environment back to the user (in the case of audible sound) or, more commonly, to a receiver in the probe. When the potential information this feedback contains has been transformed into some form within the sensory capacities of the user, the device can tell him of the existence, distance away, and something of the nature of an object; direction and size can be learned from the proprioceptive information generated by manual scanning. Three sensory modalities have been used to display the output of such devices, vibratory, tactile, and auditory; direct electrical stimulation of the skin has been suggested (Jerome and Proshansky, in Zahl, 1962), but I am not aware that this has been followed up. Although vibratory stimulation has been found satisfactory, it is difficult to obtain sufficiently intensive stimulation with the power units available; the device has to be easily portable, so that a heavy or cumbersome power unit is undesirable. The two most suitable modalities are thus touch and hearing. Both of these are employed by devices currently being worked on, but hearing is considered by many to be the most promising. Even though its use interferes with the blind traveler's normal use of this sense, it is felt that hearing offers possibilities of a much richer flow of information than does touch (Lashley, in Zahl, 1962). It is at this point that work on "travel aids" for the blind comes alongside studies of "sonar" navigation by bats, oilbirds, porpoises, and so on. The information in an auditory display of this sort can, of course, be encoded in one of several ways--for example, frequency, or intensity-modulated duration, or rate of pulses, and so forth--the "travel-aid" arousing most widespread interest at the moment being frequency-modulated.

This device, the most sophisticated of such devices currently undergoing evaluation trials, is the ultrasonic torchlike probe, details for the design of which were submitted by Dr. Leslie Kay to St. Dunstan's in 1960. The prototype which they sponsored has now reached the production-engineered stage, a batch of 150 having already been widely distributed for testing, and production of further batches modified in the light of this experience being anticipated. Perhaps I may quote a description of this device, admirable for its lucidity, which appeared in a recent periodical (Dufton, 1966):

*In its present form the sonic "torch" consists of three components--the hand-held probe with ultrasonic transmitter and receiver, a hearing-aid type earpiece through which signals are heard by the user, and a slim carrying-case in which is housed a dry-cell battery which powers the unit. . . . A beam of ultrasonic waves is emitted by a transducer in a narrow cone ahead of the user, and objects in his path return an echo to a similar receiving transducer in the head of the probe. The system is frequency-modulated, sweeping from kc 90 to kc 45. Interference effects occurring between the emitted and reflected beams permit the accurate measurement of the distance of the object, which is indicated to the user by an audible tone. The pitch of this tone--the "beat" frequency generated by the interference--is proportional to distance: low for obstacles close at hand and high for those which are distant. The nature of the surface reflecting the ultrasonic energy, the beam's angle of incidence with it, and the size and shape of the object all affect the strength of the echoes, so that the loudness and quality of the received signal provide additional information about the environment.*

There are many who would feel that the last sentence of this description could only have come from an optimist. The writer does in fact go on to stress the importance of learning if full use is to be made of the device. These same fluctuations in signal intensity have been mentioned by others concerned with evaluating the device. Since intensity is generally a better and a more usual auditory distance cue than frequency (Coleman, 1963), it is hardly surprising that such variations in signal strength have been observed to cause users of the device some confusion and conflict (Leonard and Carpenter, 1962). Also, it must be remembered that the ear is particularly sensitive to a portion of the audible frequency range, around 2,000 to 4,000 hz, and that high frequency sounds deliver more energy to the ear in a given period of time (Woodworth, 1939), so that intensity would also seem to fluctuate with frequency. Conversely, "greater intensity decreases the tone of low frequency sounds and raises the tone of high frequency sounds" (Wyburn *et al.*, 1965). Clearly there are complex interactions between frequency and intensity such that, although we are dealing here with a frequency-modulated system, it is impossible to discount the variations in signal intensity. We have already found that signal strength and reaction time are related. Chocholle (1945) showed reaction time to vary in a not very straightforward manner with frequency, but when both the intensity and the frequency of the signal were adjusted reaction times were approximately equal for signals of apparent equal loudness. All of which may suggest that, if only it were technically possible, the blind traveler might be most helped by a device having a display which was "loudness-modulated!" At first blance it might seem that an intensity-modulated system would be more satisfactory than frequency-modulation, until one reflects that those fluctuations in intensity, due to the nature of the reflecting surface, the angle of incidence, and so forth, would presumably still occur, constituting in such a system a much more serious problem. There is always the question as to whether an auditory display of whatever form is more suitable than, say, a tactile display in the increasingly noisy environment in which people have to travel. This is not the place, however, to discuss such a question.

Returning to the frequency-modulated auditory display, it seemed essential to include a number of blind *S*s in the experiment to discover what relationship, if any, existed for them between signal strength and speed of reacting. If one takes the case of a blind pedestrian, walking at reasonable pace (3 or 4 mph) who detects an obstacle in his path 6 ft ahead, he has from 1.0 to 1.4 sec to take "evasive action." Should the "obstacle" turn out to be an approaching pedestrian the time is approximately halved. The length of reaction times is then not merely of academic interest. The expectation was that the results of the two groups, sighted and blind, would show no essential differences in the controlled conditions of the experiment. In real-life situations outside the laboratory, with normal visual activity also present, the blind *S*s might be more likely to react to auditory stimuli, but not necessarily to do so more quickly.

Ten blind *S*s took part in the experiment, six men and four women; ages ranged from 28 to 63, with the majority in their 30s, giving a mean age of just over 39. Seven were totally blind, the other three having perception of light insufficient to be of any practical use. Six became blind in early childhood, three in their teens, and one at age 23. Causes of blindness are various, measles or a congenital condition being commonest, with glaucoma, buphthalmus uveitis, and retinal trouble among the rest. Occupations were equally diverse, including lawyers, piano tuners, a university lecturer, knitting machine operatives, and office workers.
Ten sighted *S*s were chosen to match this group in terms of age and sex. As far as possible, corresponding *S*s were also of roughly the same intelligence, inasmuch as this could be inferred from occupation and, very often, personal acquaintance. The process was, of course, hopelessly crude and arbitrary, but then it seemed hardly likely that intelligence would be a factor of any importance.

Experimental procedure was basically the same as in the earlier experiments, with a tone of 1,000 hz and 0.1-sec duration to be detected against a background of "white" noise, and responded to with the key. The neutral click was now used as the warning signal before the onset of the noise. Again, the temporal location of the signal within the 6 sec of noise was varied, only three time intervals being used on this occasion, 1.4, 2.6, and 3.8 sec, the more extreme values being avoided. Ten intensities of signal were used, approximately equally spaced over a range of 60 db. Time intervals and intensities were presented in randomized sequence. A signal of each intensity at each of the time intervals was presented four times, making a total of 120 readings for each *S*. The experiment was, as before, divided into two sessions, separated by a rest period, each session commencing with a suitable number of practice trials. Previously, the same level of background noise had been used with all the *S*s in an experiment, but on this occasion the level was adjusted for each individual. The 43-db signal intensity was arbitrarily chosen as the reference point, with six signal levels above (up to an intensity 42 db greater than that of the reference level), and three signal levels below (down to an intensity which could not be measured, but which was calculated as being some 18 db below the reference tone). Using the method of limits with ascending and descending series, the noise level for each *S* was ascertained at which this reference level of the signal represented the individual's signal to noise threshold. In other words, keeping the signal constant, the noise level was varied to find that level of noise which masked the signal on half the occasions on which the two were presented together. This level of noise was then used, for that individual throughout the experiment. These threshold measurements were made immediately before the first experimental session and immediately after the second to see whether any movement of the threshold had occurred during the experiment and, if so, whether this was of such an extent that some correction should be made to the data. Although movement of the threshold did take place for all but four of the twenty *S*s, it was in no case large enough to warrant correction.

The initial threshold measurements revealed no difference between the sighted *S*s and the blind; the thresholds even of those blind almost from birth, and of the piano tuners, are similar to those of their sighted contemporaries. Within both groups there is the same general relationship with age, the threshold rising with increasing age--that is, a decrease in the amount of background noise against which the signal can be detected. (A loss in sensitivity of perhaps 6 db, over more than thirty years, appears to be involved.)

A somewhat surprising picture emerges when these thresholds are compared with the measurements made at the close of the experiment. For four of the sighted *S*s the threshold appears to have remained constant, while for the remaining six it has gone down. Three of the blind *S*s show a similar threshold decrement, the other seven exhibiting a rise in threshold of about the same magnitude--a little above 2 db on average, although the precision of these measurements was limited by the apparatus used. This divergence is not easy to explain. It could be suggested that the presence of even limited visual stimulation had perhaps helped to maintain a somewhat higher level of vigilance among the sighted *S*s, but it seems equally possible to argue that this, if a factor at all, might as easily have constituted a distraction and had the opposite effect. Also the finding that, as will be seen later, the reaction times of the two groups were so similar would seem to indicate that the presence of visual stimulation for one group was not a significant factor in the situation. It will be apparent that there is, in fact, something of a paradox here. Assuming that previous experiments have revealed a general relationship between signal intensity and speed of reaction, one might well ask how it comes about that the reaction times of the two groups are so similar despite the finding that the thresholds of the seeing *S*s had tended to go down or remain the same during the experiment, while for most of the blind *S*s the trend is in the reverse direction. Looking at the results in detail, we see that nine of the sighted *S*s responded more quickly during the second half of the experiment than in the first, and only one more slowly. For the blind the figures are six and four. The nine is made up of five *S*s showing a lowered threshold and four showing no change. The tenth *S* combines a lowered threshold with slower reactions. For the six blind *S*s responding more quickly, the threshold has risen in four cases and is lower in two. Three of the four reacting more slowly show a higher threshold and one a lower. Not only is there little correspondence between the direction of threshold movement and the comparative speed of reactions in the second experimental session relative to the first, but the size of the increases or decreases in both variables appears even less related. Thus a large decrease in threshold may be accompanied by a small increase in the average speed of reactions or by a negligible slowing down. A small decrease in the threshold may be associated with reactions either slightly or considerably faster, or with somewhat slower responses. "No apparent movement" of the threshold appears equally likely to go with small or large changes in speed. Alternatively these results may be related to Deutsch's (1951) claim that auditory stimulation affects the threshold around the frequency of stimulation, except that the present results suggest that for some *S*s the threshold is lowered, and for others raised, as might be predicted on Eysenck's theory of individual differences in speed of inhibition. In view of this rather chaotic state of affairs, one is inclined to wonder whether the measured thresholds were in some way unrelated to the intervening experiment, even though the situations were so similar. The principal differences were that no warning signal was used other than the onset of noise, and that a verbal rather than a manual response was required. However, further speculation on this point would perhaps be unwarranted. Likewise, the question as to why the thresholds of so many of the blind *S*s rose between the first set of measurements and the second may also best be left in abeyance until more data are available.

The reaction times associated with the six levels of signal intensity above the threshold intensity were subjected to analysis of variance. In the initial calculations data from all twenty *S*s were included. As the outcome of these calculations revealed statistically significant interactions between *S*s and "times" (the delay or latency of the signal following the onset of noise) and between *S*s and intensities, it was not feasible to examine the main factors. When the results for blind and sighted *S*s were analyzed separately, these same two interactions were again present for both groups. To overcome this difficulty a breakdown analysis was carried out, looking at the effect of "times" and intensities for each *S* separately. (Any relationship there might be between "times" and intensities was ignored, since neither this, nor the three-way interaction, ever reached significance.) For every one of the 20 *S*s there is a significant relationship between signal intensity and reaction time beyond the 5 percent level, and 18 beyond the 1 percent level. In only five cases is the latency of the signal a significant factor, two people giving decidedly slower reactions to the signal delayed by 1.4 sec, and two others at their slowest with the 3.8-sec delay; the fifth finds 3.8 sec the slowest, but by a smaller though significant margin. As to the latency giving fastest reactions, the honors are pretty evenly divided between the 1.4 and 2.6 delays.

Ranking the over-all totals of the *S*s over the six highest levels of signal intensity, giving rank 1 to the smallest total, the summed ranks of the blind *S*s come to 94 and those of the sighted to 116. Since one of these figures could be as low as 78 simply by "chance," one must conclude that there is no undue difference in the speed of reaction of blind and sighted *S*s. Further statistical tests support this conclusion.

As usual, there are enormous differences between individuals. The fastest of the blind *S*s is, for example, 110 ms quicker in reacting, on average, than the slowest, while for the sighted *S*s this difference rises to 159 ms, as this group happens to include both the quickest and the slowest *S*s. It appears very doubtful whether the reaction times, unlike the threshold measurements, show even a general relationship with age. If one arranges the *S*s within each group by age one finds, for any given *S*, that the person immediately senior is just as likely to be quicker as slower. As a matter of interest, the quickest reactions of all are those of the oldest *S* who was over 60 years old and, on average, 33 ms ahead of the second quickest. The two slowest *S*s are only four years older than this latter, in their mid-30s.

The finding that there was no essential difference between the two groups in speed of reactions was, it may be recalled, based on results with the six highest levels of signal intensity. Turning to the threshold level of intensity, we find a response rate of 67.5 percent for the seeing, and 59.3 percent over nine of the blind *S*s (the tenth did not react at all to this level of signal intensity). The difference in the number of responses does not reach statistical significance if a *t*-test is applied. Omitting this tenth *S*, and also a second blind *S* whose few responses at this level are so slow that one wonders about their validity, a ranking test (Mann-Whitney) was carried out on the average reaction times. The result confirms an impression that (excluding the two people already mentioned) the reactions of the blind *S*s to the signal at threshold intensity were on average significantly faster than those of the seeing, the average response time for the blind being about 430 ms, with that of the seeing some 50 ms slower. If we calculate the correlation coefficients between reaction times at threshold and at higher levels of intensity, it becomes clear how it is that the results for the two groups can be so similar at higher levels of intensity and yet differ significantly at threshold. A figure of 0.564 for the seeing *S*s reaches statistical significance, but the corresponding figure for the blind, 0.213, does not, suggesting that there is little correlation between the results of this group at threshold and at greater intensity. (These correlations are, of course, not based on speed of reactions in milliseconds, but on the speed of the individual as compared with other members of his group.) With so little data to go on, it would be rash to become involved in speculation over the possibility of blind people being found to have a "special" sensitivity to signals around threshold, superior to that of the seeing and apparently not closely related to the performance of the same individual at higher levels of signal intensity. Rather, let us turn to yet another difficulty which the results present.

Some uneasiness has already been expressed over the precise relationships among measured thresholds, signal intensity, and reaction times. It seemed strange that the results of the two groups should be so similar while the measured thresholds of most of the individuals had moved in opposite directions--the thresholds of the two groups having been almost identical at the start of the experiment. A further apparent discrepancy regarding thresholds has also been noted. It might seem logical that those people reacting more quickly to signals at threshold level would also respond more frequently, if reaction time is assumed to be a measure of "detectability." But whereas the blind *S*s responded significantly faster, their rate of responding was noticeably, though not significantly, less than that of the other *S*s. If the correlations are calculated, giving rank 1 to the quickest response and to the greatest frequency of responses, we find that the figure for the seeing *S*s is 0.248 and for the blind 0.479, suggesting that for neither group do these two factors go together. On the face of it this seems such a nonsensical finding that one is inclined to dismiss it as the result of having insufficient readings at this level of intensity. On the other hand, could it perhaps reflect a motivational or confidence factor? If some *S*s decided to go for certainty, responding quite quickly on the few occasions when they felt confident of having detected a signal, others may have been inclined to "take a chance," responding more often, but more slowly, less confident that a signal had occurred. In experiments described by Swets and Green (19 ) the *S*s were found to trade time with errors in such a way as to maximize the eventual "pay-off" (monetary in their case). In the present experiment it appears very plausible that with signals of threshold intensity people concentrated either on responding as often as possible or on being "correct" when they did respond, the degree of caution being reflected in the reaction times. If this were the whole story we should, of course, have found significant negative correlations between frequency and speed, but perhaps it at least helps to explain why the correlations found are not stronger. (It is perhaps rather tempting, at this point, to be led into a discussion as to which is the more important for the blind traveler: to react quickly and confidently to a certain proportion of auditory cues or to "take a chance" on a rather larger proportion. The question, it seems, could be argued this way and that, but as such a discussion would constitute something of an intrusion in the present context, perhaps the temptation is best resisted.)

Returning at last from the realms of speculation, let us get back to the main theme of the experiment, variations in reaction time as a function of signal strength. Taking the six highest levels of signal intensity, it has been shown that for every one of the *S*s reaction time does vary with intensity, but the relationship is not a straightforward one. If it were so one would presumably expect that on moving from the total for one intensity to that for the next above it, for each *S*, one would ideally have a table containing 100 minus signs. What one finds, in fact, is that on three occasions the figures are exactly equal, while on a further 19 occasions the sign is not minus but plus. The increase in the latency of each response may be as much as 54 ms; the modal value of the distribution of these increments is 11 ms and the mean 17 ms. So one is faced with the discovery that on 22 percent of occasions an increase in signal strength either did not affect reaction time at all or was accompanied by slower reactions. On the remaining 78 occasions when increased intensity and quicker response occur together, the increase in speed averaged over a dozen responses at a given intensity for each *S* range from less than 1 ms to 133 ms, with almost half the increase falling in the range of 17 to 34 ms. A number of the increases in speed are so slight that one feels they are negligible, and that the two intensities are for that *S* "equivalent." In seven cases reaction times are only reduced by 5 ms or less, and in 15 by 1 ms or less, but it is clearly not possible to lay down any arbitrary dividing line and declare that any increase in speed not reaching that criterion shall be disregarded. If one looks at the distribution of these "disturbances" of the ideally-expected pattern (those occasions on which an increase in signal strength leads to reactions which are actually slower, equal, or only slightly quicker) it is not easy to analyze them in terms of *S*s. One can see that some individuals are more likely to show such "disturbances" in their results than others. There are, for example, four people who react at approximately the same speed to all four of the highest signal intensities. On the other hand, nine people show a substantial decrease in reaction time with every increase in intensity, except at one point, which will be dealt with later. (It may be worth noting that seven of the nine are blind.) If, however, one examines the situation in terms of intensity, things become much clearer. Moving from the first above-threshold intensity to the second (10 db to 16 db), there are only two occasions on which a substantial decrease in reaction time does not occur. With each of the next three steps the figure is doubled, so that when we move from the 30 db signal to the 36 db, nine of the *S*s react more slowly and seven in the same time or only very little less. It will be recalled that there were 20 *S*s, so that 16 represents a very considerable proportion. The final increase in signal strength, from 36 db to 42 db, is accompanied by a substantial decrease in reaction time in all but six cases, three of which are slower reactions and three equal or only slightly quicker. The situation may perhaps be seen most clearly from the later presentation of the data in graphic form, but it might be helpful meanwhile to set out the average reaction times in ms for each signal intensity, for the two groups separately, and then figures combining results of both:

|  | *10* | *16* | *22* | *30* | *36* | *42* |
|---|---|---|---|---|---|---|
|  |  |  | *(decibels)* |  |  |  |
| Blind | 366 | 311 | 284 | 278 | 277 | 256 |
| Sighted | 361 | 327 | 315 | 293 | 303 | 283 |
| Combined | 364 | 319 | 300 | 286 | 290 | 270 |

From these averages it can be seen that the reaction times of the blind *S*s decrease fairly rapidly with increasing signal intensity until a plateau is reached, beyond which there is again a steep decline. For the sighted there is no such plateau, the decline in reaction times being followed by a sudden increase before the final decrease. Chocholle (1963) finds that from a reaction time of about 400 ms to a tone of 1,000 hz at or near threshold intensity there is a rapid increase in speed of reaction as the intensity is raised to 6 or 8 db. With further increments in signal strength the gain in speed is "much slower"; between 40 db and 70 db ". . . any decrease in reaction time is minimal. . . ," and at 60 to 80 db above threshold it is more or less zero. The figures quoted are decidedly lower than the results of the present experiment, as the following will show:

| *db* | *ms* | *db* | *ms* |
|---|---|---|---|
| Threshold | 400 | 30 | 150 |
| 1 | 300 | 40 | 140 |
| 2 | 275 | 50 | 130 |
| 3 | 240 | 60 | 120 |
| 8 | 210 | 70 | 115 |
| 10 | 190 | 80 | 100 |
| 20 | 160 | Beyond | 100 |

(It must be pointed out that the above figures, taken from Chocholle, are reaction times to the cessation of a 1,000 hz tone. However, since, to quote the same author, ". . . it is generally agreed that reaction time is identical to the appearance or disappearance of a tone," and since this series happens to be unusually complete, I chose to include these figures.) This range of times, we are told, applied to young trained *S*s. With *S*s less well trained the range is from 420 to 130 ms, while with *S*s not trained and particularly slow the reactions to the highest intensities may take up

180 ms. Since the reaction times quoted by Chocholle are drawn from only three very highly trained *S*s, it is not at all surprising that they are so much shorter than those from twenty *S*s with the barest minimum of previous training and covering a wide age range. The distribution of the differences between the two sets of results (where comparisons can be attempted) is not without interest. This would suggest that reaction times (within the range of intensities covered by the present experiment) are least affected by training at threshold intensity. At 10 db the difference is very considerable, of the order of 170 ms, decreasing steadily thereafter. It seems reasonable that as the signal intensity is increased, and reaction time decreases, the effect that training can have on the reducible margin of the reaction time should also grow smaller.

What is not so readily explicable, however, is why a signal 36 db above threshold should evoke a slower response than a signal of 30 db with the seeing *S*s, and a response of essentially the same speed with the blind. Explanation is not made any easier by the convincing decrease in reaction time for both groups when signal strength is further raised to 42 db. Taking into account also the results with the 22-db signal for the blind, one is tempted to speculate as to whether, for them, there may be a range of intensities which, as far as reaction times go, are in some sense equivalent. Even a supposition of this kind would, however, not satisfactorily explain the slower response of the seeing *S*s with the 36-db signal. At the risk of being rather fanciful, it almost looks as if this particular signal is being in some way underestimated by both groups, and one wonders whether this could be connected with the fact that it is not the loudest, but is next below the loudest. If the increase from 30 to 36 db is not accompanied by a decrease in reaction time, certainly the further increase to 42 db is accompanied by a decrease which is perhaps more pronounced than one might have anticipated. Is it possible that we have here an effect which is largely due to position in the scale of values being used, similar to that so often noted for the various signal latencies? Helson's concept of the adaptation level (Helson, 1947), although originally developed in studies on vision, has been show to apply also, inter alia, to loudness, where a range of auditory intensities is involved. At first glance it would seem curious that if adaptation level is to be invoked in the present case its effect should be most noticeable so near the top of the intensity range used. However, it has also been shown that the inclusion of an extreme stimulus brings about a shift of the adaptation level in the direction of that stimulus. Now, although the *S* was seated in a soundproof cubicle, wearing headphones, there was one sound, louder than any of the experimental signals, which he heard every time he made a response: the sharp rap of the response key. On the other hand, it has been found (Brown, 1953) that there is perceptual organization involved, such that the extreme stimulus does not have this effect unless it is seen by the *S* as being relevant to the situation. If adaptation level has really anything to do with the present results, then presumably the noise from the key was being seen as relevant by the *S*s and influenced their judgment of and reaction to the signals used. Dare one suggest that perhaps consideration should be given to discarding the time-honored response key in future experiments involving auditory intensity?

Performances at each signal intensity were ranked, giving rank 1 to the fastest *S*, and correlations calculated between performance at each intensity and at every other. Although it has already been shown that there is no significant difference in the speed of reaction of sighted and blind *S*s, it was still felt that more information might be gained by looking at the two separately. For the blind the highest correlations (0.937 to 0.955) occur between the 16, 22, and 36 db intensities. All other correlations are lower, but still significant, except in two cases where the figures are as low as 0.394 and 0.358 (0.564 represents statistical significance). This suggests that there is little correlation between performance at 10 db and at 30 or 42 db. The performances of the seeing *S*s correlate most highly amongst the 16, 22, 36, and 42 db intensities (0.891 to 0.964). Performance at 30 db does not correlate significantly with that at 10, 16, or 36 db. In fact, if one looks at the correlations between performance at any one intensity and the over-all performance, this figure (seeing *S*s with the 30 db signal) is the only one which is not statistically significant. The corresponding figure for the blind, while it is higher, is none the less on the low side compared to the other correlations. Correlations between performance with the 10 db signal and over-all performance are also on the low side for both groups.

## ANALYSIS OF VARIANCE

1. Only data from the six highest levels of signal intensity were included. Data from the threshold intensity were not included since so many were missing.
2. The very few results missing for the 10-db signal were estimated and degrees of freedom reduced accordingly.
3. The analysis was first done over all results and then separately for blind and sighted.

### A. All Subjects

| *Source* | *df* | *ss* | *ms* | *Ratio* | *Sig* |
|---|---|---|---|---|---|
| Latencies | 2 | 128 | 64 | 4.0 | (.05) |
| Intensities | 5 | 15,045 | 3,009 | 188.0 | (.01) |
| Persons | 19 | 22,551 | 1,187 | 74.0 | (.01) |
| Latencies/intensities | 10 | 114 | 11 | <1.0 | |
| Intensities/persons | 95 | 5,196 | 55 | 3.4 | .01 |
| Latencies/persons | 38 | 1,091 | 29 | 1.8 | .01 |
| Latencies/intensities/ persons | 190 | 2,156 | 11 | <1.0 | |
| Residual | 1,077 | 17,703 | 16 | | |
| Total | *1,436* | *63,984* | | | |

### B. Blind Subjects

| *Source* | *df* | *ss* | *ms* | *Ratio* | *Sig* |
|---|---|---|---|---|---|
| Latencies | 2 | 94 | 47 | 3.9 | (.05) |
| Intensities | 5 | 9,043 | 1,809 | 151.0 | (.01) |
| Persons | 9 | 7,733 | 859 | 72.0 | (.01) |
| Latencies/intensities | 10 | 52 | 5 | <1.0 | |
| Latencies/persons | 18 | 389 | 22 | 1.8 | .05 |
| Intensities/persons | 45 | 1,698 | 38 | 3.2 | .01 |
| Intensities/latencies/ persons | 90 | 805 | 9 | <1.0 | |
| Residual | 537 | 6,579 | 12 | | |
| Total | *716* | *26,393* | | | |

### C. Sighted Subjects

| *Source* | *df* | *ss* | *ms* | *Ratio* | *Sig* |
|---|---|---|---|---|---|
| Latencies | 2 | 54 | 27 | 1.3 | |
| Intensities | 5 | 6,257 | 1,251 | 60.0 | (.01) |
| Persons | 9 | 14,446 | 1,605 | 76.0 | (.01) |
| Latencies/intensities | 10 | 57 | 6 | <1.0 | |
| Latencies/persons | 18 | 673 | 42 | 2.0 | .01 |
| Intensities/persons | 45 | 3,243 | 72 | 3.4 | .01 |
| Intensities/latencies/ persons | 90 | 1,363 | 15 | <1.0 | |
| Residual | 540 | 11,125 | 21 | | |
| Total | *719* | *37,218* | | | |

Because two of the two-factor interactions are significant, it is not justifiable to obtain tests of the main effects by testing against "residual." This would have to be done by breakdown analyses of, say, latency effect for each person separately, or person effect at each value of latency and intensity. This was done for latency and intensity effects, separately for each person, neglecting latency/interaction as neither this nor the three-way interaction is significant.

### D. Individual Analyses

| *Person* | *Source* | *df* | *ss* | *ms* | *Ratio* | *Sig* |
|---|---|---|---|---|---|---|
| 1 | Latencies | 2 | 55 | 28 | 2.0 | |
| | Intensities | 5 | 2,529 | 506 | 36.0 | .01 |
| | Residual | 63 | 867 | 14 | | |
| | Total | *70* | *3,451* | | | |
| 2 | Latencies | 2 | 48 | 24 | 2.4 | |
| | Intensities | 5 | 2,496 | 499 | 50.0 | .01 |
| | Residual | 61 | 610 | 10 | | |
| | Total | *68* | *3,154* | | | |
| 3 | Latencies | 2 | 62 | 31 | 2.8 | |
| | Intensities | 5 | 1,060 | 212 | 19.0 | .01 |
| | Residual | 64 | 678 | 11 | | |
| | Total | *71* | *1,800* | | | |
| 4 | Latencies | 2 | 13 | 7 | <1.0 | |
| | Intensities | 5 | 1,063 | 213 | 7.0 | .01 |
| | Residual | 64 | 1,835 | 29 | | |
| | Total | *71* | *2,911* | | | |
| 5 | Latencies | 2 | 19 | 10 | 1.1 | |
| | Intensities | 5 | 782 | 156 | 19.0 | .01 |
| | Residual | 64 | 539 | 8 | | |
| | Total | *71* | *1,340* | | | |
| 6 | Latencies | 2 | 36 | 18 | 2.6 | |
| | Intensities | 5 | 393 | 79 | 11.0 | .01 |
| | Residual | 64 | 449 | 7 | | |
| | Total | *71* | *878* | | | |
| 7 | Latencies | 2 | 62 | 31 | 3.9 | .05 |
| | Intensities | 5 | 754 | 151 | 19.0 | .01 |
| | Residual | 64 | 530 | 8 | | |
| | Total | *71* | *1,346* | | | |

## D. Individual Analyses (cont.)

| *Person* | *Source* | *df* | *ss* | *ms* | *Ratio* | *Sig* |
|---|---|---|---|---|---|---|
| 8 | Latencies | 2 | 92 | 46 | 7.7 | .01 |
| | Intensities | 5 | 277 | 55 | 9.2 | .01 |
| | Residual | 64 | 413 | 6 | | |
| | Total | *71* | *782* | | | |
| 9 | Latencies | 2 | 7 | 4 | 1.0 | |
| | Intensities | 5 | 517 | 103 | 9.0 | .01 |
| | Residual | 64 | 785 | 12 | | |
| | Total | *71* | *1,309* | | | |
| 10 | Latencies | 2 | 91 | 45 | 4.1 | .05 |
| | Intensities | 5 | 872 | 174 | 16.0 | .01 |
| | Residual | 64 | 727 | 11 | | |
| | Total | *71* | *1,690* | | | |
| 11 | Latencies | 2 | 30 | 15 | <1.0 | |
| | Intensities | 5 | 1,895 | 379 | 15.0 | .01 |
| | Residual | 64 | 1,665 | 26 | | |
| | Total | *71* | *3,590* | | | |
| 12 | Latencies | 2 | 51 | 25 | 1.5 | |
| | Intensities | 5 | 848 | 170 | 10.0 | .01 |
| | Residual | 64 | 1,084 | 17 | | |
| | Total | *71* | *1,983* | | | |
| 13 | Latencies | 2 | 61 | 30 | 3.4 | .05 |
| | Intensities | 5 | 628 | 126 | 14.0 | .01 |
| | Residual | 64 | 571 | 8.9 | | |
| | Total | *71* | *1,260* | | | |
| 14 | Latencies | 2 | 165 | 82 | 1.80 | |
| | Intensities | 5 | 685 | 137 | 3.06 | .05 |
| | Residual | 64 | 2,857 | 45 | | |
| | Total | *71* | *3,707* | | | |
| 15 | Latencies | 2 | 164 | 82 | 8.2 | .01 |
| | Intensities | 5 | 899 | 180 | 18.0 | .01 |
| | Residual | 64 | 644 | 10 | | |
| | Total | *71* | *1,707* | | | |
| 16 | Latencies | 2 | 119 | 60 | 1.8 | |
| | Intensities | 5 | 3,060 | 612 | 19.0 | .01 |
| | Residual | 64 | 2,142 | 33 | | |
| | Total | *71* | *5,321* | | | |
| 17 | Latencies | 2 | 54 | 27.0 | 1.60 | |
| | Intensities | 5 | 256 | 51.0 | 3.07 | .05 |
| | Residual | 64 | 1,064 | 16.6 | | |
| | Total | *71* | *1,374* | | | |

## D. Individual Analyses (cont.)

| *Person* | *Source* | *df* | *ss* | *ms* | *Ratio* | *Sig* |
|---|---|---|---|---|---|---|
| | Latencies | 2 | 56 | 28.0 | 2.9 | |
| 18 | Intensities | 5 | 341 | 68.0 | 7.0 | .01 |
| | Residual | 64 | 608 | 9.5 | | |
| | Total | *71* | *1,005* | | | |
| | Latencies | 2 | 30 | 15.0 | <1.0 | |
| 19 | Intensities | 5 | 583 | 117.0 | 5.0 | .01 |
| | Residual | 64 | 1,457 | 23.0 | | |
| | Total | *71* | *2,070* | | | |
| | Latencies | 2 | 9 | 5.0 | <1.0 | |
| 20 | Intensities | 5 | 308 | 62.0 | 9.0 | .01 |
| | Residual | 64 | 441 | 7.0 | | |
| | Total | *71* | *758* | | | |

Latencies significant:

7 (.05), 8 (.01), 10 (.05), 13 (.05), and 15 (.01).

Ranking the performances of the sighted *S*s at each of the six highest levels of signal intensity, for purposes of correlation, giving rank 1 to quickest reactions:

| *Subject* | *10* | *16* | *22* | *30* | *36* | *42* |
|---|---|---|---|---|---|---|
| | | | *(decibels)* | | | |
| 1 | 8 | 3 | 3 | 3 | 2 | 3 |
| 2 | 2 | 2 | 2 | 2 | 3 | 2 |
| 3 | 4 | 5 | 4 | 6 | 5 | 6 |
| 4 | 9 | 10 | 10 | 4 | 10 | 10 |
| 5 | 5 | 4 | 5 | 9 | 4 | 5 |
| 6 | 10 | 8 | 6 | 5 | 9 | 7 |
| 7 | 7 | 9 | 8 | 10 | 8 | 9 |
| 8 | 6 | 6 | 9 | 8 | 7 | 8 |
| 9 | 3 | 7 | 7 | 7 | 6 | 4 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 |

Correlations

| *db* | *10* | *16* | *22* | *30* | *36* | *42* |
|---|---|---|---|---|---|---|
| *16* | 0.685 | | | | | |
| *22* | 0.588 | 0.903 | | | | |
| *30* | 0.248 | 0.539 | 0.624 | | | |
| *36* | 0.685 | 0.964 | 0.891 | 0.479 | | |
| *42* | 0.709 | 0.903 | 0.903 | 0.600 | 0.943 | |

Ranking the performances of the blind *S*s at each of the six highest levelf of signal intensity, for purposes of correlation, giving rank 1 to the quickest reactions:

| *Subject* | *10* | *16* | *22* (*decibels*) | *30* | *36* | *42* |
|---|---|---|---|---|---|---|
| 1 | 9 | 5 | 5 | 2 | 4 1/2 | 4 |
| 2 | 8 | 8 | 6 | 4 | 6 | 3 |
| 3 | 4 | 1 | 1 | 6 | 1 | 1 |
| 4 | 10 | 10 | 10 | 10 | 10 | 10 |
| 5 | 5 | 4 | 3 | 5 | 4 1/2 | 6 |
| 6 | 1 | 2 | 2 | 3 | 3 | 5 |
| 7 | 2 | 3 | 4 | 1 | 2 | 2 |
| 8 | 3 | 6 | 7 | 7 | 7 | 8 |
| 9 | 6 | 7 | 8 | 9 | 8 | 7 |
| 10 | 7 | 9 | 9 | 8 | 9 | 9 |

Correlations

| *db* | *10* | *16* | *22* | *30* | *36* |
|---|---|---|---|---|---|
| *16* | 0.745 | | | | |
| *22* | 0.623 | 0.951 | | | |
| *30* | 0.394 | 0.623 | 0.673 | | |
| *36* | 0.615 | 0.937 | 0.955 | 0.755 | |
| *42* | 0.358 | 0.733 | 0.794 | 0.745 | 0.870 |

Ranking over-all performances, for the purpose of correlating these with performance at each signal intensity, giving rank 1 to quickest reactions:

| *Subject* | *Blind* | *Sighted* |
|---|---|---|
| 1 | 5 | 3 |
| 2 | 7 | 2 |
| 3 | 1 | 5 |
| 4 | 10 | 10 |
| 5 | 4 | 4 |
| 6 | 3 | 8 |
| 7 | 2 | 9 |
| 8 | 6 | 7 |
| 9 | 8 | 6 |
| 10 | 9 | 1 |

Correlations

| *df* | *Blind* | *Sighted* |
|---|---|---|
| 10 | 0.710 | 0.721 |
| 16 | 0.976 | 0.988 |
| 22 | 0.951 | 0.927 |
| 30 | 0.710 | 0.552 |
| 36 | 0.985 | 0.976 |
| 42 | 0.818 | 0.951 |

Correlating speed of over-all reactions with age of *S*s:

| *Blind* | *Sighted* |
|---|---|
| 0.267 | 0.127 |

These figures fall below that of 0.564 which marks the 5 percent level of significance. However, one gets the impression, in calculating the correlation for the sighted *S*s, that if it were not for the fact that the oldest *S* also happened to be the quickest of the twenty, thus causing a big discrepancy in any attempt to link age and speed, then a much higher correlation might emerge. Accordingly, this *S* (No. 10) was omitted and ranks adjusted to take account of this. If this is done, one gets a result of 0.681, which is more than the 0.600 which marks the 5 percent level of significance with an "*N*" of nine. Thus it would seem that for the seeing *S*s there is a relationship between age and speed of reacting, if the one rather remarkable individual is excluded. Whether such a cavalier attitude to a negative instance would be justified, however, is another question.

Average Speed of Responses at Threshold

| *Reaction Time in ms* | | *Ranks* | |
|---|---|---|---|
| Blind | Sighted | Blind | Sighted |
| 374 | 530 | 1 1/2 | 17 |
| -- | 430 | -- | 6 |
| 443 | 440 | 8 | 7 |
| 723 | 486 | 19 | 12 |
| 488 | 453 | 13 | 9 |
| 474 | 494 | 11 | 15 |
| 414 | 577 | 3 | 18 |
| 374 | 489 | 1 1/2 | 14 |
| 421 | 496 | 4 1/2 | 16 |
| 468 | 421 | 10 | 4 1/2 |
| | | *71 1/2* | *118 1/2* |

Ranking the average reaction times at threshold for comparison with similar ranks for performance over the six higher signal intensities:

| *Rank at Threshold* | | *Rank over Higher Levels* | |
|---|---|---|---|
| **Blind** | **Sighted** | **Blind** | **Sighted** |
| 1 1/2 | 9 | 5 | 3 |
| -- | 2 | -- | 2 |
| 5 | 3 | 1 | 5 |
| 9 | 5 | 9 | 10 |
| 8 | 4 | 4 | 4 |
| 7 | 7 | 3 | 8 |
| 3 | 10 | 2 | 9 |
| 1 1/2 | 6 | 6 | 7 |
| 4 | 8 | 7 | 6 |
| 6 | 1 | 8 | 1 |

Correlation for the blind:

rho = 1-6(94 1/2)
$9(9^{2} -1)$
1-567 = 1-0.7875 = 0.2125

Correlation for sighted:

rho = 1-6(72)
$10(10^{2} -1)$
1-432 = 1-0.4363 = 0.5637

With $N$ = 9, figure of 0.600 necessary for significance at 5 percent level; 0.212 therefore not. With $N$ = 10, figure must reach 0.564, which is exactly the result here for the sighted.

Ranking number and speed of responses at threshold, giving rank 1 to quickest and most frequent reactions:

| *Blind* | | *Sighted* | |
|---|---|---|---|
| Speed | Number | Speed | Number |
| 1 1/2 | 7 1/2 | 9 | 9 1/2 |
| -- | -- | 2 | 5 1/2 |
| 5 | 2 | 3 | 2 |
| 9 | 9 | 5 | 9 1/2 |
| 8 | 7 1/2 | 4 | 7 |
| 7 | 6 | 7 | 2 |
| 3 | 2 | 10 | 8 |
| 1 1/2 | 4 1/2 | 6 | 2 |
| 4 | 2 | 8 | 4 |
| 6 | 4 1/2 | 1 | 5 1/2 |

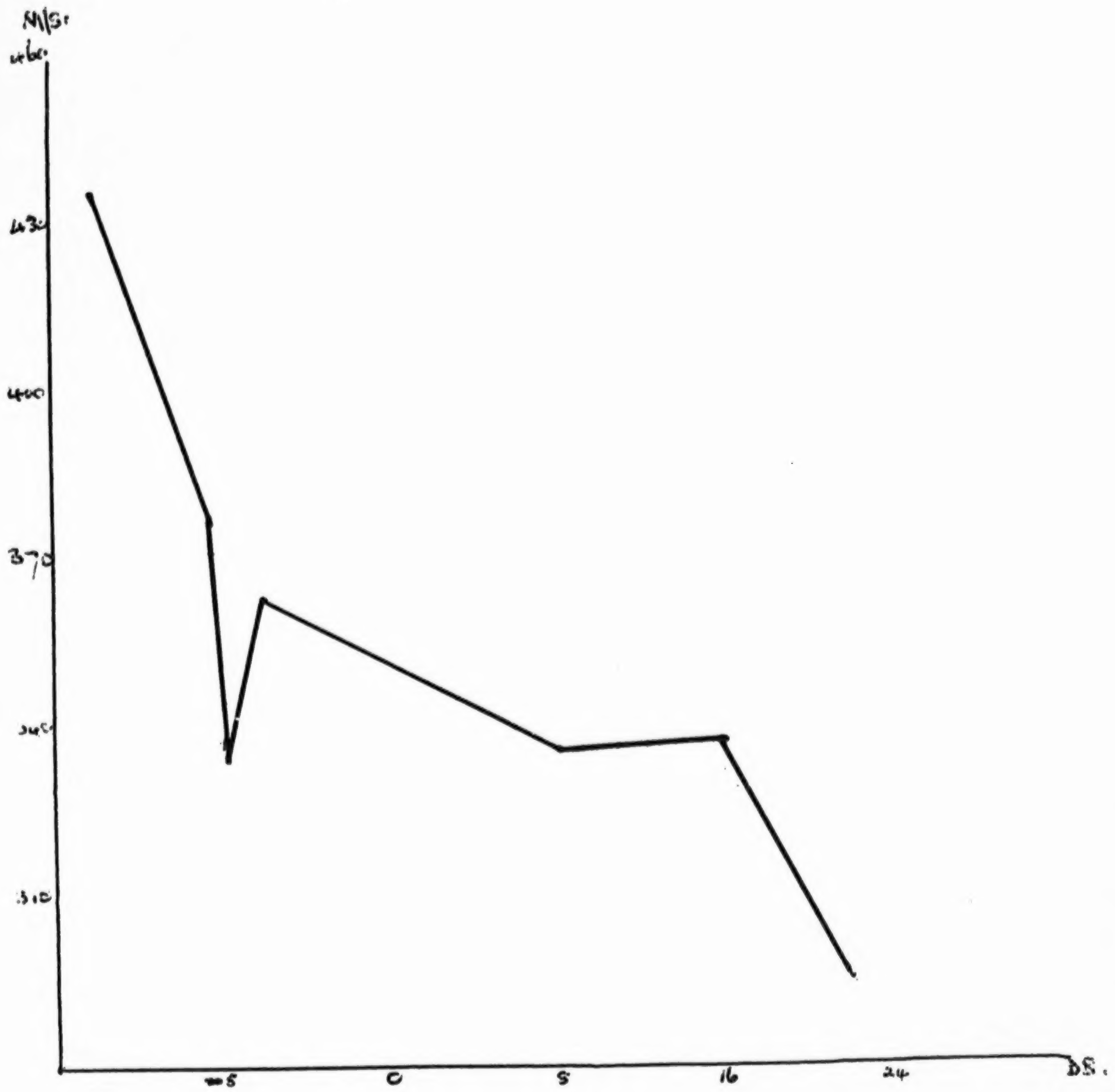
Correlation for blind:

rho = 1-6(62 1/2)
$9(9^2 -1)$
1-375 = 1-0.521 = 0.479

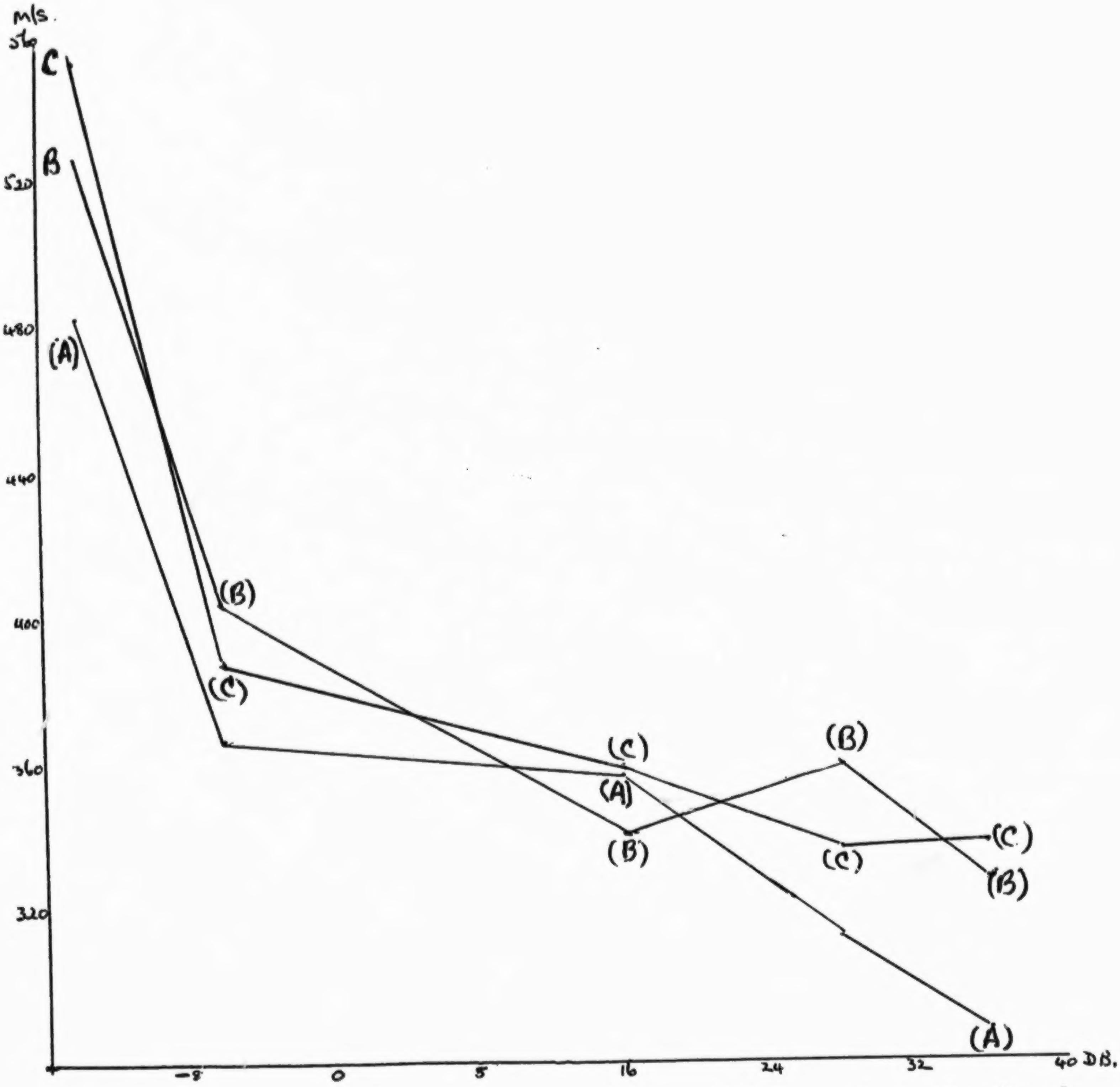
Correlation for sighted:

rho = 1-6(124)
$10(10^2 -1)$
1-744 = 1-0.752 = 0.248

Neither result achieves statistical significance.

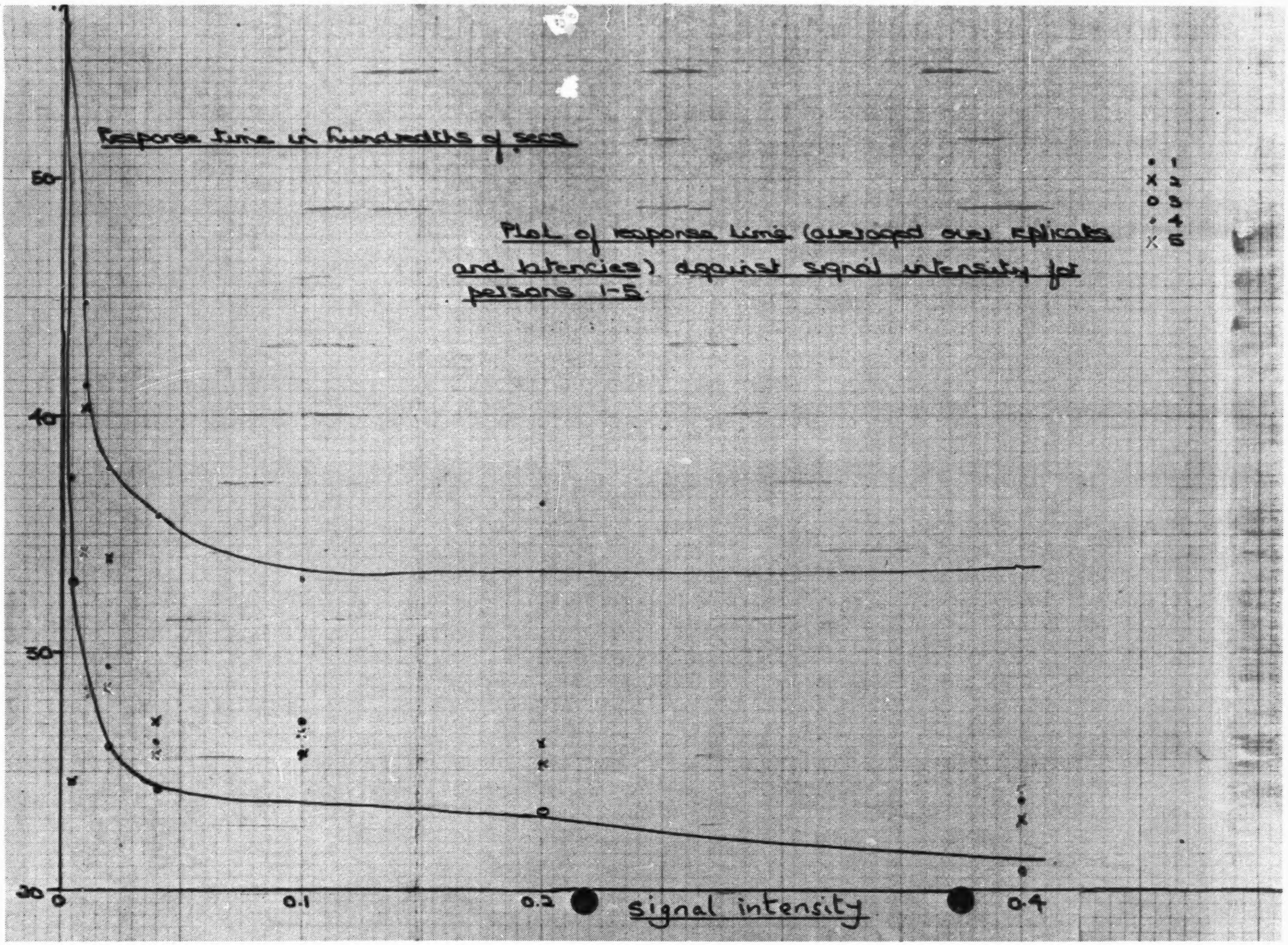


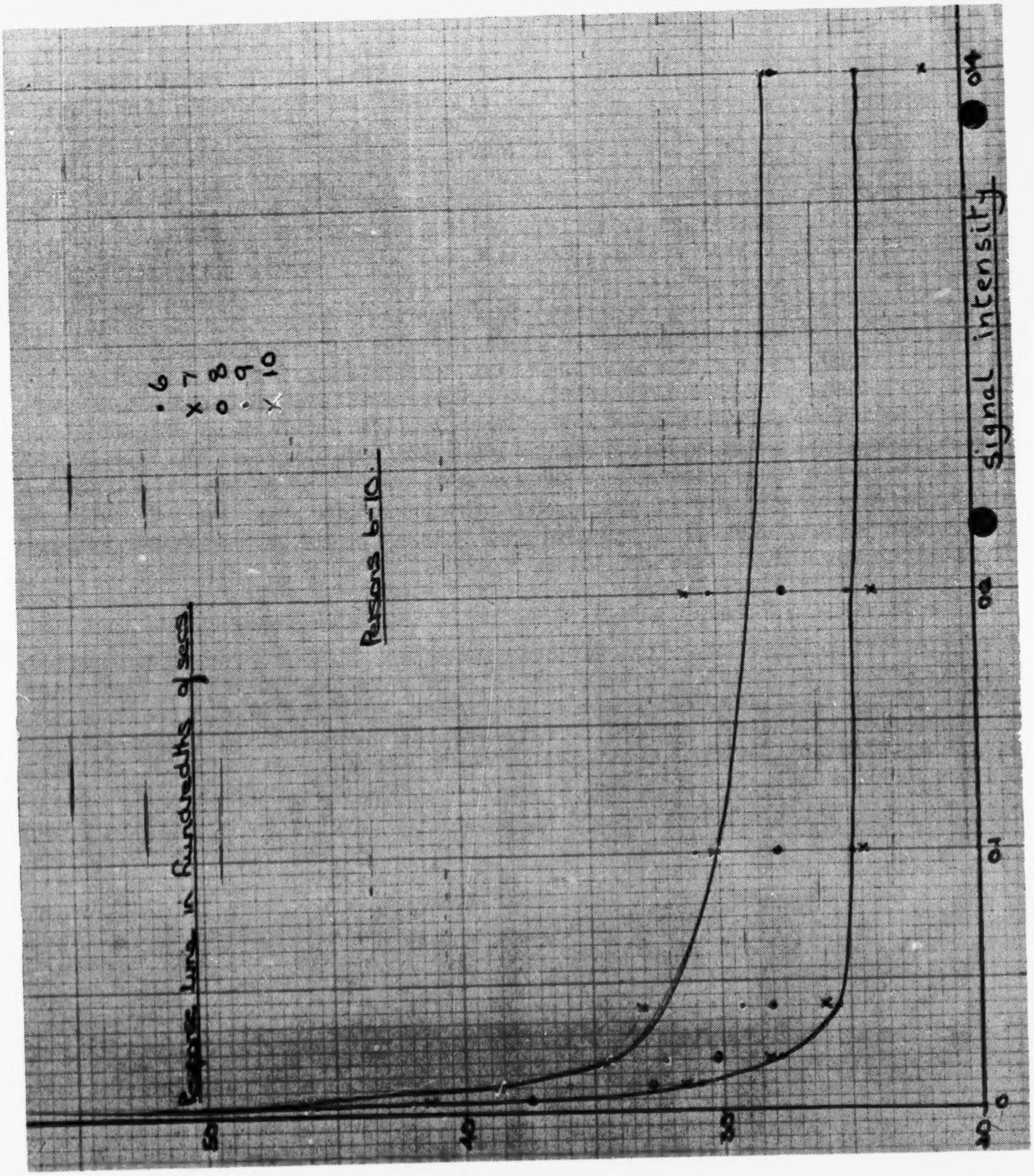
| DB | M/S. |
|---|---|
| -14 | 439 |
| -9 | 378 |
| -8 | 337 |
| -6 | 361 |
| 8 | 328 |
| 16 | 336 |
| 22 | 297. |



(A)— "equal" warning signal
(B)— "constant" warning signal.
(C)— "click" 〃

| D.B. | "Click" | "Constant" | "Equal" |
|---|---|---|---|
| -14 | 555 | 528 | 484 |
| -6 | 390 | 407 | 369 |
| 16 | 363 | 343 | 359 |
| 28 | 337 | 361 | 314 |
| 36 | 344 | 331 | 257 |


Response time in hundredths of secs
Plot of response time (averaged over replicates and latencies) against signal intensity for persons 1-5.
• 1
× 2
o 3
· 4
X 5
50
40
30
30
0
0.1
0.2
0.4
signal intensity


Response time in hundredths of secs
Persons 6-10.
• 6
x 7
o 8
· 9
X 10
50
40
30
20
0
01
02
04
Signal intensity

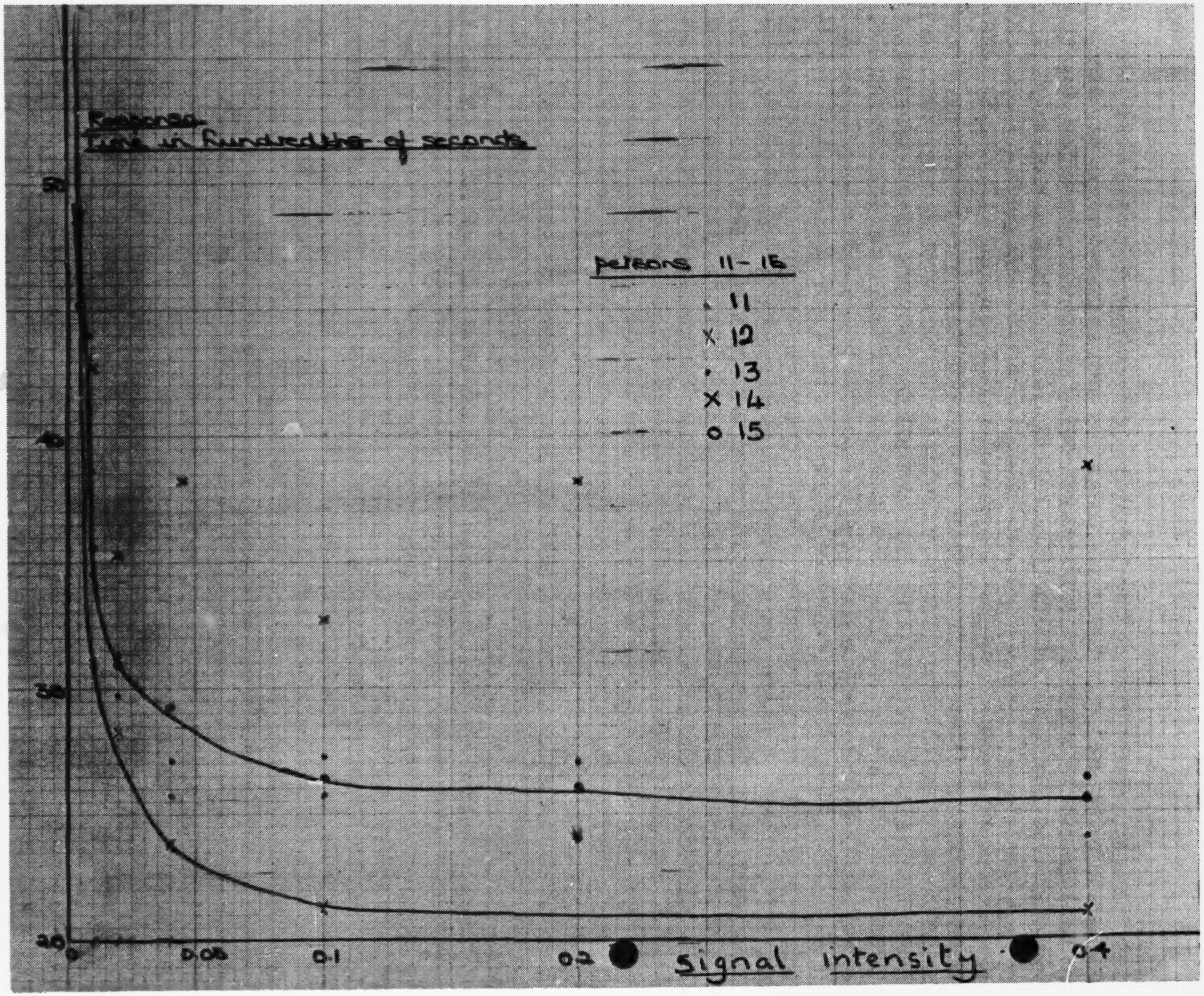
## Relation Between Response Time and Intensity

*(1)* Calculations were made for each person, ignoring effects of latency. *(2)* Results for signals of threshold intensity were included, using a simple average of these results. *(3)* Examination of Graphs 1 to 4 suggests that response time $y$ and intensity $x$ are related by a curve of the form $(y - a) = c(x - b)^{-k}$, where the factors $a$ and $b$ represent new asymptotes, the $b$ value representing the intensity for which there is no response. A figure of -6 db seems likely, but to the accuracy of a first analysis a value of 0 is assumed. The $a$ value represents the supposed response time however great the intensity (a mechanical reaction time). For purposes of analysis it is assumed that this had been reached at 42 db. *(4)* $y$ values are thus corrected by subtraction of 42 db level and then required to fit a curve of form $z = cx^{-k}$, or $\log_{10}z = a - k(\log_{10}x)$; that is, $\log z = b_0 + b_1 \log x$. *(5)* This is carried out by least squares analysis. Person 2 is the analysis of only 5 results as no response occurred at threshold level. Persons 8 and 11 are from 5 results only, as there are zeros in the results for the 10 db level. Persons 4, 14, and 16 are not suitable for analysis in this manner as they have extreme values included in their results.

| *Persons* | *Total ss* | $b_1$ | $b_0$ | *ss due to reg.* | | *%* |
|---|---|---|---|---|---|---|
| 1 | 1.03 | -0.67 | -0.37 | (0.43) | 0.91 | 88 |
| 2* | 0.48 | -0.62 | -0.06 | (0.69) | 0.41 | 85 |
| 3 | 0.62 | -0.49 | 0.08 | (1.20) | 0.47 | 76 |
| 5 | 1.30 | -0.76 | -0.56 | (0.28) | 1.15 | 88 |
| 6 | 1.69 | -0.89 | -0.92 | (0.12) | 1.59 | 94 |
| 7 | 0.60 | -0.54 | -0.06 | (0.87) | 0.59 | 98 |
| 8* | 1.58 | -0.99 | -1.38 | (0.04) | 1.13 | 72 |
| 9 | 0.51 | -0.42 | 0.04 | (1.10) | 0.36 | 71 |
| 10 | 0.49 | -0.47 | 0.08 | (1.20) | 0.44 | 90 |
| 11* | 1.22 | -0.98 | -0.90 | (0.13) | 1.12 | 92 |
| 12 | 1.00 | -0.62 | -0.27 | (0.54) | 0.79 | 79 |
| 13 | 1.80 | -0.88 | -0.91 | (0.12) | 1.54 | 80 |
| 15 | 1.75 | -0.93 | -0.86 | (0.14) | 1.72 | 98 |
| 17 | 0.52 | -0.37 | 0.22 | (1.66) | 0.28 | 54 |
| 18 | 1.09 | -0.55 | -0.27 | (0.54) | 0.60 | 55 |
| 19 | 0.27 | -0.31 | 0.47 | (2.95) | 0.19 | 70 |
| 20 | 0.82 | -0.61 | -0.27 | (0.54) | 0.75 | 91 |

% denotes percentage total sum of squares accounted for by regression ($c = 10^{b_0}$).

*Three straight line graphs are plotted in graph 5.


Response
Time in hundredths of seconds
persons 11- 16
. 11
x 12
. 13
x 14
o 15
50
40
30
20
0
0.05
0.1
0.2
0.4
Signal intensity

## REACTION TIMES TO SEVERAL FREQUENCIES

Although these experiments have been concerned with any effect on reaction times of variations in signal intensity, with the equipment and the soundproof cubicle available it seemed a pity not to take at least a cursory glance at any influence of frequency. In particular, it was desired to reexamine the finding of Chocholle, who in studies already referred to, ". . . ascertained that at equal loudness the times were approximately equal, whatever the frequency." With weak intensities of signal he found reaction times unaffected by frequency. With medium and strong intensities, reaction times were at their slowest when the signal frequency was around 2,000 hz, becoming shorter as the frequency was increased or decreased, intensity being kept constant. In another paper (Chocholle, 1963), he displays reaction time data obtained with various intensities of signal at frequencies of 50, 250, 1,000, and 10,000 hz. Taken across any given intensity, those associated with the 50 hz signal are the shortest, those with the 1,000 hz tone the longest, the 250 and 10,000 hz tones giving approximately equal times and falling between these two. It may be noted in passing that the 50 hz tone, although giving fastest results, seemed to be tolerable only up to perhaps 45 db. The 250 and 10,000 hz tones are not plotted beyond 70 db, while the 1,000 hz tone is bearable over a range of more than 100 db. Some idea of the complex relationship between intensity and frequency has already been given in the introduction to the previous experiment. If, however, the physical intensity of signals of different frequency is so adjusted that they sound equally "loud" to the *S*, then the assertion is that reaction times to the signals will be "approximately equal."

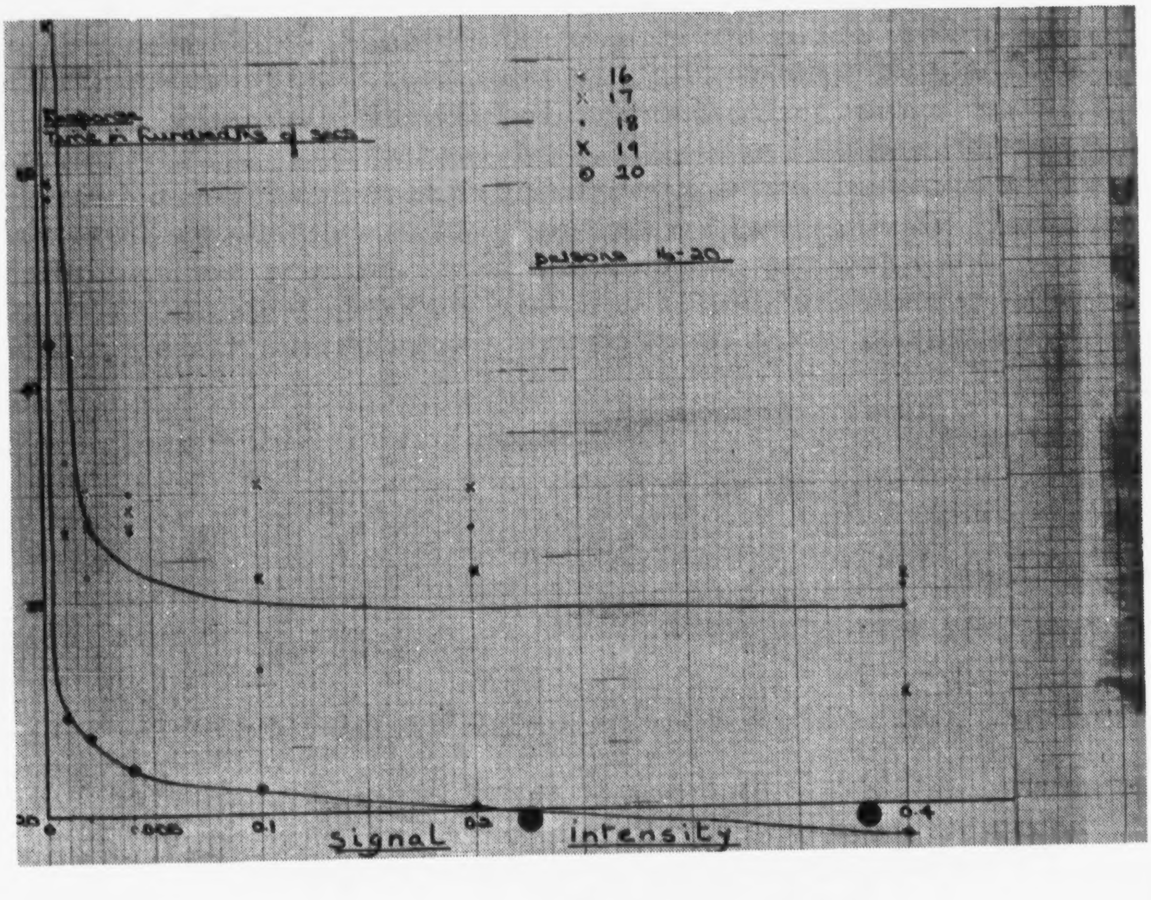
Five people took part in the following small experiment, three male and two female, ages 28, 28, 32, 36, and 38.

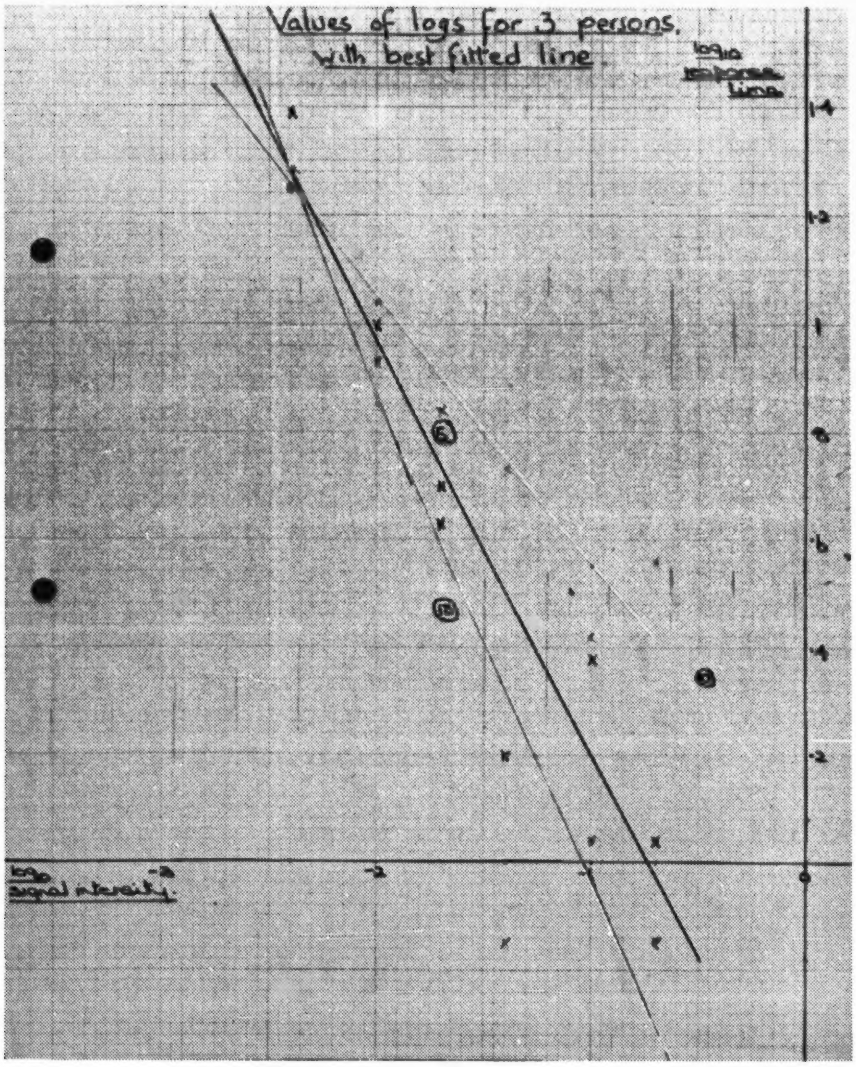
The signals were again tone pulses, 0.1 sec in duration, of five different frequencies: 250, 500, 1,000, 2,000 and 4,000 hz. As before, the experiment was divided into two sessions for each individual, with a rest break between. In the first session the *S*, seated in the soundproof cubicle and wearing the headphones, was presented with a sample of the "white" noise and of the tone frequency (selected at random from among the five) to be explored first; the intensity of this tone, whatever its frequency, was 45 db. Noise and tone were then presented together, the *S*'s task being to report whether he thought that both were present or simply noise. Keeping the intensity of the tone constant, but varying that of the background noise, this procedure was repeated to a point where the *S* changed his verdict. In other words, the method of limits was used, with ascending and descending series, to find that level of noise against which the 45-db tone appeared to be of threshold intensity, that is, on approximately half of the occasions when that level of noise was presented with the tone the *S*'s verdict would be "noise," and on the other half "both." A similar procedure was then followed for each of the remaining frequencies.

In the second part of the experiment, which followed after an interval of some 10 to 15 minutes, the procedure was basically that of the preceding experiments. The "click" warning signal was used, preceding by 0.3 sec the onset of noise, the level of this being varied according to the frequency of the signal to be detected against it. The levels used were in fact those already established as sufficient to mask to threshold intensity, for that individual and for that signal frequency, a tone of 45 db intensity. The signal was not, however, a tone of 45 db, since too little data would have been gathered at this level; but a 0.1-sec tone of 67 db, occurring 1.4, 2.6, or 3.8 sec after the beginning of the noise. The *S*'s task was now simply to respond by pressing the key "as quickly as possible" (always with the same hand) when he heard the signal. The latency and the frequency of the signal were, of course, varied in a random fashion and the session commenced with an appropriate period of practice.

It has generally been observed in previous experiments that 60 "trials," or stimuli, constitute just about the reasonable maximum for one experimental session, beyond which effects of fatigue or monotony or both become apparent. The length of time which this occupies, approximately 25 to 30 minutes, is considerably longer than that recommended by Chocholle, but it seems that his stimuli were presented at a much faster rate. In Chocholle's work the individual stimuli of a batch might be separated by 2 to 4 sec. In the experiments described here this interval might be typically five times as long, partly because the signal is now embedded in 6 sec of background noise, partly because of the number of manual operations the experimenter had to perform between signals. In fact, in the present experiment this number and this interval was so increased that some *S*s found the rate of presentation uncomfortably slow. With five frequencies, three latencies, and only 60 trials the number of repetitions of a particular signal was limited to four. I am fully aware that 12 reaction times per frequency is an absurdly small number (which, however, could not be helped, given this type of experimental design which has much in its favor), but nevertheless it is hoped that the results may have some value albeit limited.

An examination of the results by analysis of variance revealed a significant interaction (.001 level) between frequency and *S*, so that the main factors could not be tested further, except for signal latency which also gave a figure significant beyond the .001 level. To overcome this difficulty the results for each *S* were analyzed separately. For all five the effects of frequency on reaction time reached statistical significance, two beyond the .01 level and three beyond the .001. Signal latency was seen to be a significant factor in only two cases (.025), where the 3.8-sec delay gave rise to reactions which were noticeably slower. In Figure 4 average reaction times are plotted against signal frequency. Although the 250 and 500 hz tones give essentially the same results, the other frequencies can scarcely be said to yield reaction times which are "approximately equal," as predicted: discrepancies occur of the order of 50 to 60 ms. In Figure 5 are shown the average levels of background noise which it was necessary to present along with a 45 db tone to mask it to threshold intensity; and which were, of course, presented with the tones 22 db above threshold to which the responses were made. Although the curves in the two figures are not exactly alike, the similarity nevertheless seemed sufficiently striking to suggest looking for any correlations between fastest reactions and least background noise, and this was accordingly done for each *S*. To achieve statistical significance, even at the 0.05 level, a figure of 0.900 is necessary in this case. The figure for one *S* is 0.975, and for a second 0.900. Two more are only a little less, 0.875, and only one correlation is small (0.400). This would seem to suggest





that the variations in reaction times are to be seen, to some extent, as variations in the amount of noise present. What in fact seems to be happening is something like this: we take a number of signals of different frequency and add background noise; in order to equate the different frequencies for subjective loudness we vary the amount of added noise; now we find that the *S*, instead of reacting with equal speed to the signals which are subjectively equal, reacts at different speeds to the signals which are objectively not equal. Threshold measurements were also made in the previous experiment to present *S*s with signals which would be of equivalent value for each individual. It was noted in the discussion of that experiment that there appeared to be a lack of any very obvious relationship between the threshold measurements and the reaction times, and the present results reinforce this feeling.

It appears as though explanation of the present results could be attempted along any one of three ways. First, it could be suggested that the threshold measurements were faulty, that the signals to which responses were obtained were not equally loud, and that Chocholle's assertion has not in fact been tested. It would surely be begging the question to say that the threshold measurements must have been faulty, since reaction times are not "approximately equal," unless further evidence can be adduced. One curious feature is that for all five *S*s the 2,000 and 4,000 hz tones were detectable against only relatively low background noise, whereas it is widely recognized that the ear shows greatest sensitivity around these frequencies. It may be apposite here to recall Chocholle's finding that reaction times are at their longest around 2,000 hz, which in no way explains, but perhaps complements, the above. Second, it may be hypothesized that the two situations are not exactly congruent, that sounds which are subjectively equal when a verbal response regarding presence or absence is involved are not necessarily equal when a manual response "as quickly as possible" is required on detection. This would seem a strange and rather difficult hypothesis to maintain, and again involves begging the question. The third approach would be to assume that the threshold measurements were accurate, and that the signals responded to were equally loud, but that Chocholle's claim does not hold, at least not for this particular situation. Perhaps there is something essentially different about a situation where not signal but noise is adjusted. For that matter, Chocholle did not present his tone signals against any intentional background noise. The table below shows a breakdown of the original correlations between speed of reaction and amount of background noise present. Correlations are shown between *(1)* speed of reaction and ascending frequency (giving rank 1 to fastest reaction and to highest frequency), and *(2)* amount of background noise present and ascending frequency (giving rank 1 to highest frequency and to least noise).

| *Subject* | *Correlations Between* | | |
|---|---|---|---|
| | *Freq. and Speed* | *Freq. and Noise* | *Speed and Noise* |
| A | 0.325 | 0.200 | 0.875 |
| B | 0.575 | 0.600 | 0.975 |
| C | 0.900 | 0.200 | 0.400 |
| D | 0.975 | 0.800 | 0.875 |
| E | 1.000 | 0.900 | 0.900 |

For *S*s A and B both correlations are low, but those between speed of response and amount of noise is the important factor. For *S*s C, D, and E correlations are high (perfect in one case) between increasing frequency and increasing speed, and lower between frequency and noise. It is suggested then that these results show

(a) a tendency for reaction time to decrease as signal frequency increases, within the limits of the range investigated;

(b) a tendency for reaction times to vary with the amount of background noise, irrespective of the signal, being longer where this is greater.

It may or may not seem meaningful to attempt to separate signal and noise in this way, but it would certainly help to explain the present results if it is postulated that the individual's attitude to the background noise--which was, after all, 60 times longer than the signal--may have constituted one important determinant of the length of reaction times. As to the effect of frequency, it is obvious that (a) above runs completely counter to Chocholle's conclusion, based on much more extensive studies. However, perhaps the experimental procedure he used is, after all, so different from that used here that close comparison of the results should not be sought. Absence of measurable levels of background noise and a faster rate of stimulus presentation have already been mentioned as characterizing Chocholle's study. Another major difference is that his stimuli were presented in batches (20 successive stimuli of identical frequency and intensity), so that after the first the *S*s, of whom Chocholle himself was one, knew exactly what to expect of the next 19 signals. It seems not unlikely that such predictability might tend to flatten out any effects of frequency on reaction times.

*Analysis of Variance (including all* Ss*)*

| *Source* | *df* | *ss* | *ms* | *Ratio* | *Sig.* |
|---|---|---|---|---|---|
| Frequency | 4 | 445 | 111.000 | 50.742 | |
| Subjects | 4 | 843 | 211.000 | 96.457 | |
| Latencies | 2 | 60 | 30.000 | 13.714 | 0.01 |
| Frequency/subjects | 16 | 177 | 11.000 | 5.029 | 0.01 |
| Frequency/latencies | 8 | 30 | 3.750 | 1.714 | -- |
| Subjects/latencies | 8 | 26 | 3.250 | 1.485 | -- |
| Residual | 32 | 70 | 2.188 | | |
| Total | *74* | *72,123* | | | |

*Analysis of Variance (individual subjects)*

| *Subject* | *Source* | *df* | *ss* | *ms* | *Ratio* | *Sig.* |
|---|---|---|---|---|---|---|
| A | Frequency | 4 | 60.67 | 15.168 | 14.929 | 0.001 |
| | Latency | 2 | 1.20 | 0.600 | 1.693 | -- |
| | Residual | 8 | 8.13 | 1.016 | | |
| | Total | *14* | *14,922* | | | |
| B | Frequency | 4 | 79.667 | 19.917 | 9.086 | 0.01 |
| | Latency | 2 | 35.800 | 17.900 | 8.166 | 0.025 |
| | Residual | 8 | 17.533 | 2.192 | | |
| | Total | *14* | *10,482* | | | |
| C | Frequency | 4 | 169.667 | 42.417 | 7.585 | 0.01 |
| | Latency | 2 | 20.600 | 10.300 | 1.842 | -- |
| | Residual | 8 | 44.733 | 5.592 | | |
| | Total | *14* | *15,277* | | | |
| D | Frequency | 4 | 146.33 | 36.583 | 36.257 | 0.001 |
| | Latency | 2 | 16.60 | 8.300 | 8.226 | 0.025 |
| | Residual | 8 | 8.07 | 1.009 | | |
| | Total | *14* | *11,875* | | | |
| E | Frequency | 4 | 166.33 | 41.583 | 16.250 | 0.001 |
| | Latency | 2 | 12.20 | 6.100 | 2.384 | -- |
| | Residual | 8 | 20.47 | 2.559 | | |
| | Total | *14* | *19,567* | | | |

## Conclusions

When these experiments were planned it was hoped to analyze thresholds in the way first proposed by Tanner and Swets (19--) and to relate reaction time to these thresholds. However, to be able to do this a considerable number of "false positive" responses would have been needed from the *S*s, that is, responses in the absence of any signal. In the experiments reported here a signal, however weak, was always present; but it was hoped that false positives would have shown by responses occasionally preceding the signal. These occurrences were exceedingly rare--about 1 percent of the trials. This suggests that a reaction time task is psychologically very different from the detection task usually used in threshold experiments.

1. *Intensity:* Reaction times to auditory signals (tone pulses) heard against "white" noise become shorter as signal intensity is increased, over a range from 14 db below threshold to 42 db above. Signals of greater intensity were not included, and responses to those of less intensity were too few to be investigated.

2. The effect of a given increment in signal strength is not uniform. In the fifth experiment, for instance, an increase of 10 db from threshold is accompanied by a reduction in the average reaction time of about 90 ms, and further increments of 10 db by reductions of approximately 60, 20, and 10 ms. Studies cited suggest that the reductions continue to diminish until, after about 80 db is reached, further increases in signal strength do not give rise to further shortening of reaction times. Although data from experiments 1, 2, and 4 would seem to suggest that something like the same picture can be seen with below-threshold signals, results from experiment 3 do not support this, and the situation is in any case rather unclear.

3. Although it has been stated above that "reaction times. . . become shorter as signal intensity is increased," such a statement requires some caution. While it is true in a general way, one finds particular individuals responding with equal speed to two, three, or even four signal intensities. Again, it was a common feature of all five experiments involving intensity as such that the signal intensity next below the highest being used "evoked" unduly slow reactions, slower than those to the intensity next below it. (For experiment 4 this is only true for one of the three conditions.) Similarly, examples occur (in experiments 1 and 4) where the highest intensity included does not produce the quickest reactions. This kind of breakdown in the relationship seems most likely with intensities of 28 to 40 db, but also occurs below this level. In other words, the prediction that an increase in signal strength will lead to shorter reaction times seems to hold less good as intensity increases. An extremely tentative explanation of some of these findings is put forward in terms of an "adaptation level" phenomenon.

4. *Latency*. Five latencies, or periods of delay of the signal, were used, ranging from 0.2 sec to 5.0 sec, in steps of 1.2 sec; but not all of these were used in every experiment. The results showed that for each experiment the latency next below the longest being used gave the quickest responses. Where the data were analyzed individually this general tendency was found to reach statistical significance for 5 out of 20, and 2 out of 5 *S*s. The latencies evoking quickest reactions were either 2.6 or 3.8 sec, depending on the presence or absence in the given experiment of signals delayed by 5 sec. The presence or absence of this relatively long delay also appears relevant to performance at the 0.2-sec latency which appears, as it were, to be "depressed" by the inclusion of the 5 sec latency.

5. *Warning Signal:* A warning signal which consisted of a tone of the same frequency, duration, and intensity as the signal to be detected was found to go with fastest reactions. A click as the warning signal produced responses just slightly faster than those associated with the third type of warning signal (a tone of the same frequency and duration as the signal,

but of fixed high intensity). It would seem reasonable to expect quickest responses when the *S* is given in advance most information about the stimulus to be detected, but nevertheless it is of some interest to attempt a measure of the extent of the advantage. This seems to be least around the middle of the intensity range used, but is quite considerable (a saving of up to 60 to 70 ms) at either end.

6. *Blind/Sighted:* Within the intensity range investigated there appears to be no significant difference between blind and sighted *S*s in the speed of their reactions to a given signal of more than threshold intensity.

7. With signals of threshold intensity the blind *S*s gave reaction times significantly shorter than those of the sighted. The difference is of the order of 50 ms.

8. The performance of the sighted *S*s with signals of threshold intensity is positively correlated with their performance at higher levels of signal intensity; this is very much less the case with the blind.

9. The superior sensitivity of the blind at threshold, apparently almost unrelated to their performance at higher intensities, clearly leaves the way open for postulating some kind of "special" threshold sensitivity, developed perhaps by constant attention to weak auditory cues; but the data are too few to warrant such a postulation.

10. Although the blind *S*s react more quickly to the threshold signals than do the sighted, their reactions are also fewer, though the difference falls short of statistical significance. An attempt is made to explain the situation in terms of a possible "trading" between time and errors.

11. *Threshold Measurements:* There appears to be a general relationship between thresholds, as measured here, and age. With increasing age the threshold also rises, that is, there is a decrease in the amount of background noise against which a given signal can be detected.

12. The initial threshold measurements yielded results which were virtually identical for the blind and sighted *S*s.

13. The terminal threshold measurements revealed that the threshold had gone down for most of the seeing *S*s (that is, an increased sensitivity to the signal) while for most of the blind it had gone up (that is, decreased sensitivity to the signal).

14. Clearly, if the two groups start with identical thresholds (12), but the thresholds of one group thereafter tend to move up while those of the other tend downward (13), it is not easy to explain why the reaction times of the two groups are nevertheless so similar (6), given that reaction times are related to signal intensity (1), which is presumably affected by movements of the threshold. This is only one of a number of points raised which cast doubt and confusion on the exact nature of the connection between threshold measurements and reaction times in this experimental situation. (See experiments 5 and 6.)

15. *Frequency:* Over a range of 250 to 4,000 hz, there appears to be a tendency for reaction times to decrease as frequency rises. The picture is, however, more complicated than this would suggest, because. . .

16. There is also a tendency for reaction times to be influenced by the amount of background noise present, being longer where this is greater, and . . .

17. The amounts of background noise necessary to mask to threshold intensity 45 db tones of differing frequency appear to yield a roughly sigmoidal curve when plotted against frequency (see Fi 5, Exp 6). Most noise needed to be added with the 500 hz signal, and least with the 2,000 hz.

18. *The Individual:* One feature was especially noticeable in the results of every experiment, and has also been stressed by most writers on reaction times. More striking than any differences attributed to changes in signal intensity, or frequency, or latency, or any other variable that may be manipulated, are the differences between individuals. Even where threshold measurements have been made, and it is assumed that people are responding to what is subjectively precisely the "same" stimulus, differences between individuals of 100 to 150 ms are not uncommon. When allowances are not made for possible differences in threshold, but *S*s are simply presented with objectively identical stimuli, the differences in reaction times may be so marked that, as in Experiment 4, the results of the two fastest and the two slowest individuals do not overlap, despite age, sex, and many other possible influences being the same for all four.

19. Whether reaction times showed any sex differences could not be clearly established because adequate provision was not made for testing this variable. What did appear was that speed of reacting has very little if anything to do with age within the age range involved in any one experiment; the greatest age range included ages 27 to 63. Comparisons between different experiments are obviously of very little validity in this case.

20. *"Travel Aids":* Finally, the question remains to be asked, "Has any of the foregoing any relevance whatsoever to the design of auditory displays of the output of the type of 'travel aid' which has been described?" Rightly or wrongly, it is felt that the verdict on this must lie chiefly with those who are more intimately connected with developing and evaluating such "aids," and who may generally be assumed to know more about *(1)* what is technically possible, *(2)* what is most desirable from the user's point of view, as when one strikes a balance between the amount of incoming information the user is given to process and the user's wish to maintain a reasonable walking speed. In case this attitude seems rather negative, a few points may be picked out as possibly worth considering. Conclusions 1, 2, and 3 (above) might, for example,

be taken to suggest that signal intensity, relative to that of the background noise, should be kept fairly high if one wishes to avoid the likelihood of quite large changes in reaction time being caused by quite small fluctuations in signal intensity. This suggestion is perhaps reinforced, from a slightly different angle, by conclusion 16. If, on further investigation, conclusion 15 were to be confirmed, it would seem desirable to reverse the present displays so that nearer objects produce higher frequency signals, which in turn produce faster reaction times (where these are most needed). Since it is generally agreed that environmental noise has most of its energy and its masking effect at lower frequencies (at perhaps 500 hz and below), a reversal would also fit in with the suggested requirements for intensity. Conclusion 10 brings to mind something like a model for the kind of "trading" between safety and speed (or effort) which a user of the device might be felt to engage in; while conclusion 6 gives some support for assuming that much of the data on reaction times gathered from seeing *S*s may prove equally applicable to the blind. Finally, and perhaps appropriately, conclusions 18 and 19 might serve as a reminder (if any were needed) that one must expect individual performances with such a device to vary markedly, and that variation may not be predictably linked with anything so concrete as the present age of the user or age at onset of blindness--at least not by reaction times.

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# A CLOSED CIRCUIT TV SYSTEM FOR THE VISUALLY HANDICAPPED

S. M. Genensky, P. Barak, H. L. Moshin
and H. Steingold

At various periods during the past two years we have experimented with the prototype of a device which could help the visually handicapped with their reading and writing. The term "visually handicapped" refers to persons with poor vision who are unable to read or write or who have difficulty reading and writing even with the aid of eyeglasses, but who could be helped by a visual aid which increases image magnification, light intensity or brightness, or some combination of these factors.

We originally considered purely optical devices to accomplish this goal, but all the optical instruments that we considered were either too expensive, cumbersome, complicated or delicate. The major problem with using passive optical systems is that they are all "light losers," that is, they are subject to light losses due to reflection from optical surfaces and due to absorption, diffusion and scattering within optical media.

The germ of the idea for the system we have been experimenting on came from Mr. David S. Grey, a mathematician and consultant in optical design, who suggested that we use a closed circuit TV system. He pointed out that a closed circuit TV system can be a light amplifier, and also that cheap, compact TV components are readily available.

Authors note:

*Just prior to the publication of this paper, we learned that A. M. Potts, M.D., D. Volk, M.D. and S. W. West, B.S.E. published a note in the April, 1959 issue of the* American Journal of Ophthalmology *(Vol. 47, No. 4) entitled "A Television Reader" which describes a prototype closed circuit TV system which (1) was to be used for reading, (2) had a magnification of 10X, (3) held the TV camera fixed, and (4) moved reading material clipped to a moveable stage by means of manual gear drive. We regret that we did not know of this work prior to the publication of our RAND Memorandum, RM-5672-PR,* A Closed Circuit TV System for the Visually Handicapped, *for we would have also enjoyed acknowledging it there.*

A recent reference to the use of closed circuit TV for assisting visually handicapped people with their reading has come to our attention. It describes the use of a hand-held TV camera to accomplish the task.[1] Our early experience with a camera mounted in a biaxial gimbal and guided manually by a long rod indicated that such a guidance system would not be satisfactory because it is uncomfortable to manipulate the rod over long periods of time. We believe that a system using a hand-held TV camera would prove to be even more uncomfortable to operate than the rod-controlled device just described.[2] We have restricted our TV camera to rotation about a fixed but arbitrary horizontal axis and are using an electrically operated servomechanism to move the camera.

## THE PROTOTYPE SYSTEM[3]

The prototype system consists primarily of (a) a TV monitor resting on a shelf, which may be moved toward or away from the user and which may be raised or lowered slightly to suit his convenience, (b) a TV camera that may be rotated about a fixed but arbitrary horizontal axis by means of an electrically operated servomechanism and (c) a working surface used to support reading and writing materials. (See Figure 1.) A small portion of those materials may be seen on the TV screen at any particular time. (See Figure 2.) The user rotates a knob connected to a synchro transmitter, which in turn causes a synchro receiver to move the TV camera across a line of the reading or writing material. Line advancement is achieved by sliding the material toward the back of the working surface.

Although some mention of the system's cost is necessary, the figures given here are not complete. They do not include for example, the cost equivalent of the time spent at and away from RAND by the authors and their colleagues, David S. Grey and Dexter P. Cooper, in discussions concerning the design, operation and evaluation of the system. We have spent

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[1] *Chester A. Weed, "Electronic Image Enlargement for the Partially Sighted (A Description of Apparatus and Preliminary Results,"* Hartford Hospital Bulletin, *Vol. XXIII, No. 1 (March, 1968), Hartford, Connecticut.*

[2] *In correspondence with Dr. Genensky, dated March 26, 1968, Dr. Weed pointed out that he and his colleagues have modified their reading device since the publication of the paper cited on p. 1. Now "the camera is held stationary above the desk and the printed page is moved beneath the lens by means of a mechanical stage."*

[3] *The terms "the prototype system" and "the system" are used interchangeably to refer to the closed circuit TV system discussed throughout the remainder of this Memorandum and described in more detail in Appendixes A and B.*

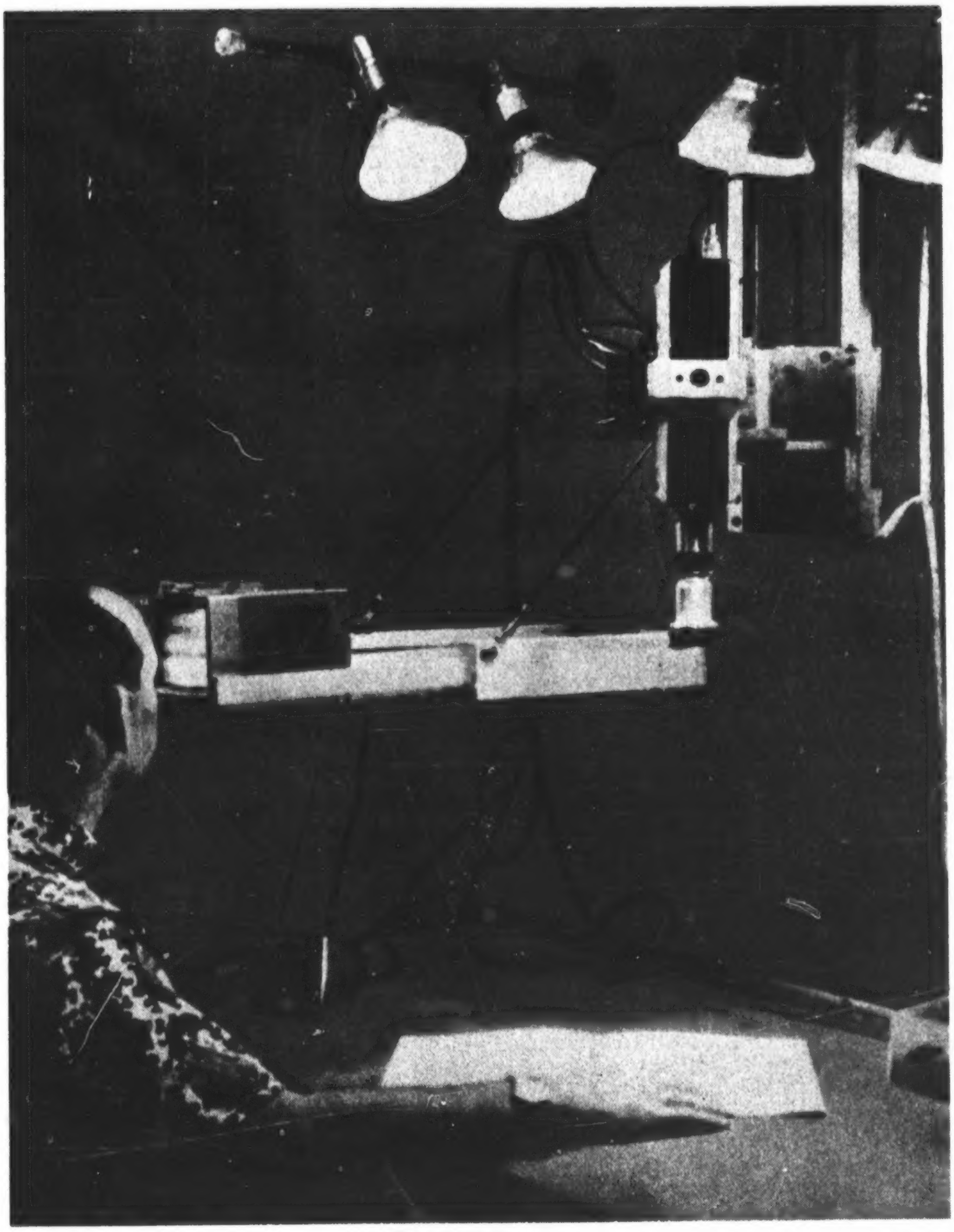
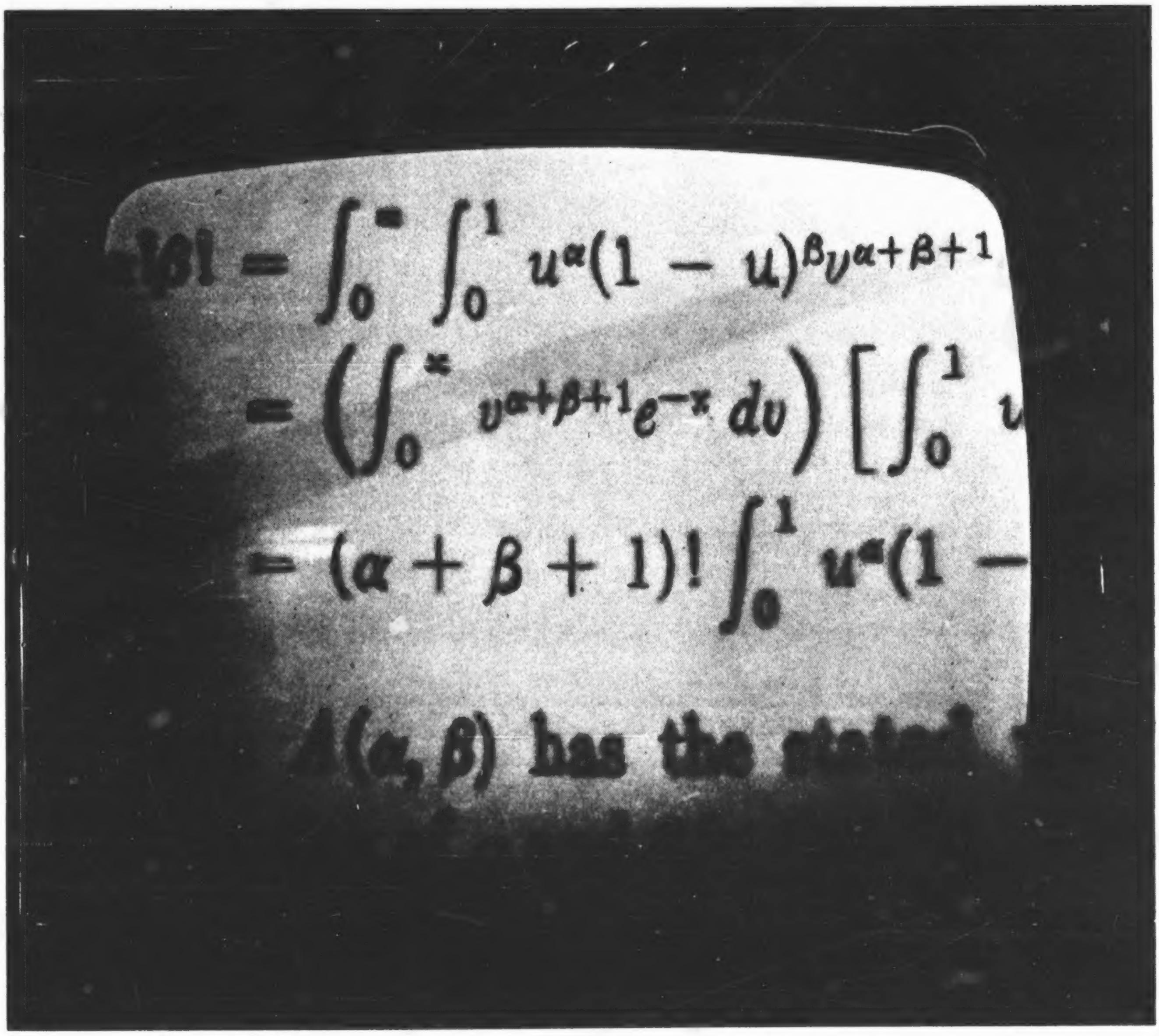


*Figure 1. General View of Prototype System in Operation*

less than $750 on hardware, including $100 for replacement of a vidicon that showed signs of wear. Less than $3000 was spent on technician labor, and most of this cost is nonrecurring. It is doubtful that an exact duplication of the prototype system will be built. However, before a cost estimate of a commercial system can be made, that system will have to be designed. Such a system will no doubt include some and perhaps all of the improvements discussed in Design Recommendations and the Problem of X-Radiation.



$$!\beta! = \int_0^\infty \int_0^1 u^\alpha(1-u)^\beta v^{\alpha+\beta+1}$$

$$= \left(\int_0^\infty v^{\alpha+\beta+1} e^{-v}\, dv\right) \left[\int_0^1 u\right.$$

$$= (\alpha+\beta+1)! \int_0^1 u^\alpha(1 -$$

$(\alpha, \beta)$ has the stated

*Figure 2. Typical View of Reading Matter on TV Monitor*

## EXPERIENCE WITH THE PROTOTYPE SYSTEM

The prototype system is installed in the office of one of the authors (Dr. Samuel M. Genensky) and is used daily to assist him with his reading and writing.[4] He has been able to adjust to the system quite readily. For example, he was able to master in a matter of minutes the rather complex maneuver of writing on ruled paper clearly and along a straight line, while at the same time observing on the TV screen only a portion of the writing paper, a part of his right hand, and the writing end of his pencil or pen. His integration with the system has been so complete that when he is writing with a pencil, makes a mistake and erases the mistake, he occasionally finds himself blowing on the TV screen in an attempt to remove the erasures from the writing paper.

The system allows him to read type magnified about three times while seated in a natural position with his right eye about two inches from the monitor screen, and it eliminates the necessity of his either holding printed material close to his face, or bending over it so as to bring his right eye within a couple of inches of the printed page--actions which, though effective, frequently are very uncomfortable. Using no magnification the system also permits him to write while sitting comfortably erect with his right eye about an inch from the monitor screen and with pen or pencil and writing tablet at desk level. Before the prototype system was developed, he wrote by bringing his eyes to within a couple of inches of the writing paper which rested on either an inclined board, a stack of books or a desk top--maneuvers which again, though effective, were often very tiring.

[4] *Dr. Genensky has corneal scars on both eyes, the result of an infection of unknown origin which occurred in 1927 shortly after his birth. Partial iridectomies were performed on both of his eyes in November 1927. He lost all vision in his left eye, probably from glaucoma either prior to or shortly after the operation. He has vision in his right eye, sees through a "cat's eye"-shaped opening in the iris of that eye, and measured at 20 feet, his visual acuity is approximately 8/500. However, he is able to resolve the 15 line on a Reduced Snellen Chart unaided if the printed material is brought to within about an inch and a half of his right eye. The opening through which he sees does not respond to dilation medication so no direct observation of the posterior chamber of the eye is possible short of surgical procedures. He has no measurable color insensitivity, has good light-gathering power and a large, though less than normal, right-eye visual field.*

The system has also been tested by four other visually handicapped persons:

(a) a woman of about thirty-five who lost all of the vision in her right eye and the macular vision in her left eye as a result of uveitis. This woman was able to manipulate the system with ease, and with it she was able to read printed material that she could not otherwise resolve except with the aid of a strong magnifying glass. The material was magnified about three times, and her left eye was about four inches from the monitor screen.

(b) a man of about seventy who has macular degeneration in both eyes. His uncorrected visual acuity is 8/300 in the right eye and 20/200 in the left eye. Vision in his left eye can be corrected to 20/100 using a Feinbloom 2.2 magnifier with a reading attachment. This gentleman, who enjoys playing the cello, can no longer read music while playing his instrument. Using the system, he was able to read a portion of a musical score that had been magnified approximately 2.8 times from a viewing distance of approximately three feet from the screen of the TV monitor.

(c) a man in his late fifties who has partial optic atrophy in both eyes, and who can count fingers at one foot. Using the system, this gentleman was able to read newspaper type magnified twelve times from a viewing distance of about an inch from the screen of the TV monitor. He reports that he is unable to read such type with any other visual aid he has tried.

(d) a man in his early seventies who has macular degeneration in both eyes, and whose uncorrected visual acuity is 20/200 in the right eye and 20/100 in the left eye. Using the system, this man was able to read printed Hebrew magnified eight times from a viewing distance of about eighteen inches from the screen of the TV monitor. Unlike the people described in (a), (b) and (c), he showed little enthusiasm for the system. In part this may have been due to a language barrier, which made communication slow and difficult.

## DESIGN RECOMMENDATIONS AND THE PROBLEM OF X-RADIATION

The prototype system was built as an experimental device and even though it has undergone many modifications and will undoubtedly undergo further changes, what is important is that it works, and it is fully operational (when it is not undergoing some type of alteration). The following modifications are being made or are being considered. We believe that they would improve the system's flexibility, ease of operation and overall quality.

Relocate the dimmer switch, which controls the lighting system, and the switch that controls the vertical motion of the TV camera to a more convenient position for the user. (Currently, the user must reach over to the far right-hand corner of the working surface to operate these controls.)

Install a TV-monitor support that permits the user not only to move the monitor horizontally toward or away from his face, but also allows him greater flexibility in moving it vertically. (The prototype system permits only minor adjustments in the height of the monitor above the working surface, and this precludes the possibility of persons of widely varying heights seated in chairs of varying heights from operating the system comfortably.)

Replace the current lighting system by one which produces less heat in the vicinity of the working surface. Since only a small portion of the working surface is seen by the TV camera at any particular time, it may be possible to sufficiently illuminate the area viewed, for example, by fitting a reflector and a ring shaped lighting unit on the TV camera or its lens adapter.

Attach a left margin guide to the working surface. At the magnification at which the prototype system is used (which, measured on the face of the monitor is approximately $1x$ to $17.6x$) if writing or reading materials are not placed directly perpendicular to the camera, blurring may occur at the extremities of the viewed line due to limited depth of field. For letter or legal size writing material and most books, a stationary, properly placed margin guide would make this problem easily avoidable. If a margin guide were installed that could be rotated and translated, it could be of value in conjunction with a wider variety of writing and reading materials.

Install a damping device to eliminate or drastically reduce the camera vibration induced by the operation of the servomechanism. This vibration can cause image degradation and can also damage the camera and its delicate vidicon.

Modify the automatic light control circuits of the TV camera and the contrast control circuits of the TV monitor to increase the useful contrast. At present the light intensity at the face of the monitor is greater than desired at the sought-after contrast levels. This gives rise to glare, which in turn causes some unnecessary fatigue. Other glare-reducing techniques could be used, including placing a filter over the face of the TV monitor.

Replace the hand-operated controls that govern the motion and focusing of the TV camera by foot-operated controls. This would greatly increase the usefulness of the current system by allowing the user to have both hands free for such things as writing or turning the pages of a book.

Develop and install a zoom lens that (a) is compatible with the TV camera used in this or a similar system, (b) can focus to, say, within a few inches of the working surface, (c) has a useful magnification range, and (d) can be adjusted remotely. The device we are currently using to vary image magnification, although working, is rather makeshift and awkward, and we believe it should be replaced by more sophisticated equipment--though this could prove to be an expensive innovation.

### X-Radiation

Whenever one is in proximity to high voltage one may be exposed to harmful X-rays. The criterion used to determine whether a TV receiver is safe with respect to X-ray emission is that at normal distances from the TV screen and over long periods of time (~ 1000 hr/yr), the whole-body X-radiation dose is increased by no more than 5 percent over the natural background dosage one receives from cosmic rays.[5] The X-ray emission from the TV monitor used in the prototype system is expected to be much less than the maximum allowed by this criterion, because the monitor uses an accelerating voltage of 8KV. This voltage is low compared to that used in larger TV receivers. On the other hand since users of the prototype system tend to bring their eyes within a few inches of the monitor screen, they may be receiving an X-ray dosage which is of the order of one hundred times greater than that which an observer would receive if he viewed the screen at a normal viewing distance.[6] Even so, the X-ray emission of the monitor is very probably still so low that this is not a problem. Nevertheless, we intend to investigate this question further.

Should the X-radiation in close proximity to the monitor screen turn out to be higher than is acceptable, it could be reduced to a safe level by simply placing a small thickness of glass over the present monitor screen.

## POTENTIAL USERS

Precise data on the number of people in the United States who fall within our definition of "visually handicapped" are unavailable; however, the number probably is greater than two hundred thousand and less than two million.[7] We believe that some improved versions of the prototype system would be of great value to many of these people.

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[5] *M. Eleccion, "X-radiation from Color Television Receivers,"* IEEE Spectrum, *July 1968, pp. 95-104.*

[6] *"Electro-optical Characteristics of Television Systems,"* RCA Reviews, *March 1948, pp. 5-37. O. H. Schade defines normal viewing distance as any TV screen-to-viewer distance which is greater than four and less than seven times the vertical height of the screen being viewed.*

[7] *This estimate is based upon information derived from hearings before the Subcommittee on Public Health and Welfare of the Committee on Interstate and Foreign Commerce, House of Representatives, Ninetieth Congress, First Session, on H. R. 12843, a bill to amend the Public Health Service Act to provide*

Such a system could be used, for example, to help students read and write at their desks, in a library, in their homes, etc. Variations of the system could also help students (a) to see, very likely for the first time, material which their teacher or one of their classmates writes upon a blackboard, or (b) to watch a demonstration or experiment which would otherwise be only partially visible to at most two or three of them at a time.

Other variations of the system could be used to assist visually handicapped men and women with their work in the office, in the factory and in the home. They could, for example, permit such people (a) to type, and at the same time, to see what they are typing, (b) to write and read while seated in a natural position at a desk, table or bench and (c) to assemble or manipulate parts they might not otherwise be able to handle because either they could not see them, or even if they could, the parts would have to be brought dangerously close to the eyes for proper examination.

The prototype system or a modification of it, would be of great value to many elderly people who, for one reason or another, are no longer able to read newspapers, magazines, or books with the aid of a magnifying glass. Books with oversized type are currently available for use by such people (as well as other visually handicapped persons), but unfortunately these books are expensive, limited in number and, out of necessity, use a large but standard type size. A closed circuit TV system with a wide range of magnification could transform instantaneously the writing or printing on any piece of paper into a wide range of oversized writing or lettering.

## Appendix A

## DETAILS OF CONSTRUCTION

For ease of description throughout this and the following appendix, each part of the prototype system is consistently designated by a numeral in parentheses. (See Figures 3 through 5.)

The system consists of a Concord, Model MTC-12, television camera (1), equipped with an extension tube that serves as a variable-length lens adapter (2), which accommodates a

*for the establishment of a National Eye Institute in the National Institutes of Health, October 31 and November 1, 1967. Serial No. 90-16. U.S. Government Printing Office, Washington, 1968, pp. 38, 146, 150-153 and 165.*

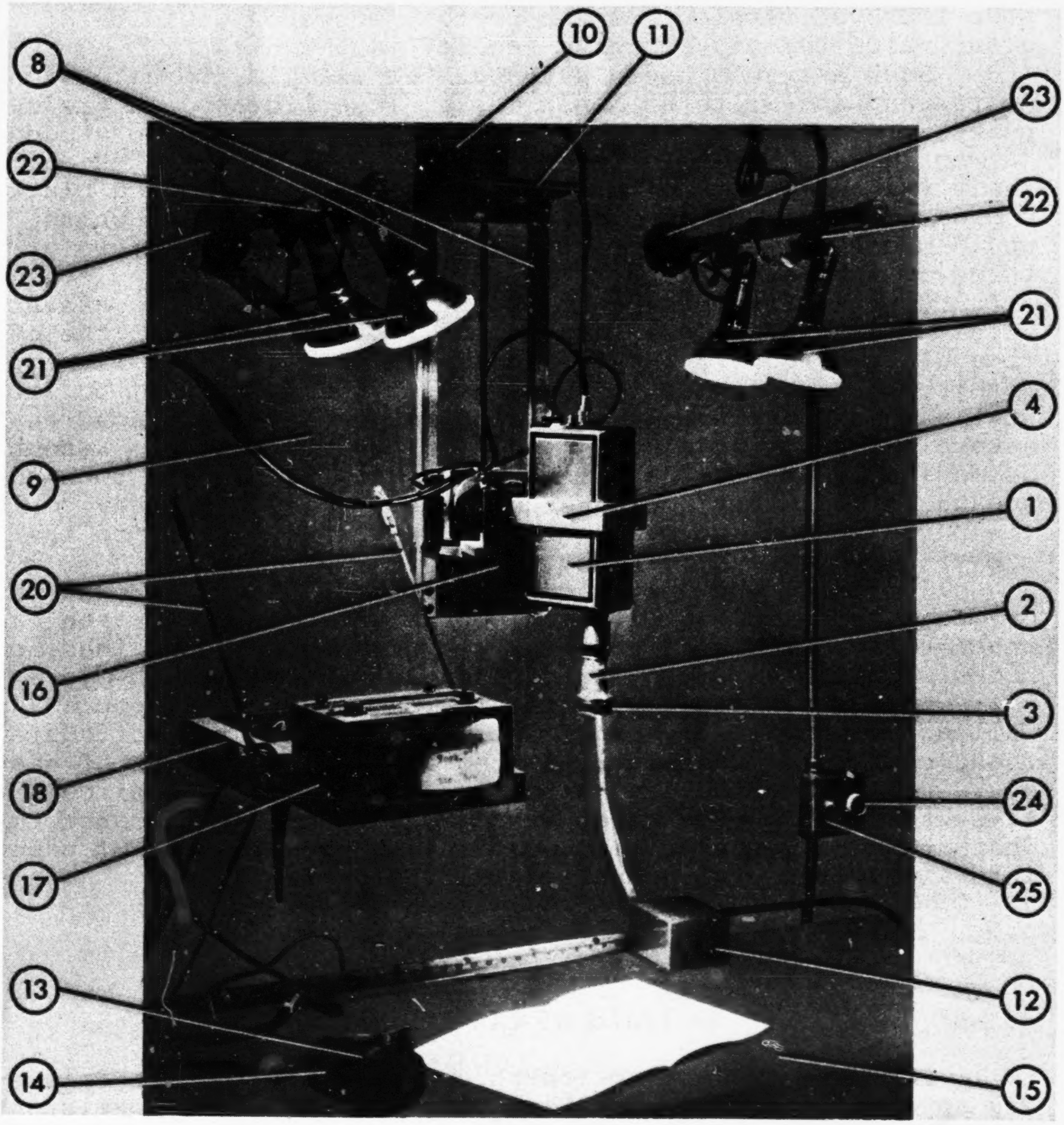


*Figure 3. General View of the Prototype System*

Schneider-Kreuznach Symmar f5.6 100 mm lens (3). The camera is mounted in a yoke (4) that may be rotated by means of a gear train (5) and synchro receiver (6). The yoke (4), gear train (5), and synchro receiver (6) are supported by an aluminum housing (7), which rides on two vertical aluminum members (8) of rectangular cross-section rigidly bolted through a wooden backing (9) to the wall. The camera (1) is raised or lowered by a motor (10) rigidly attached to a horizontal

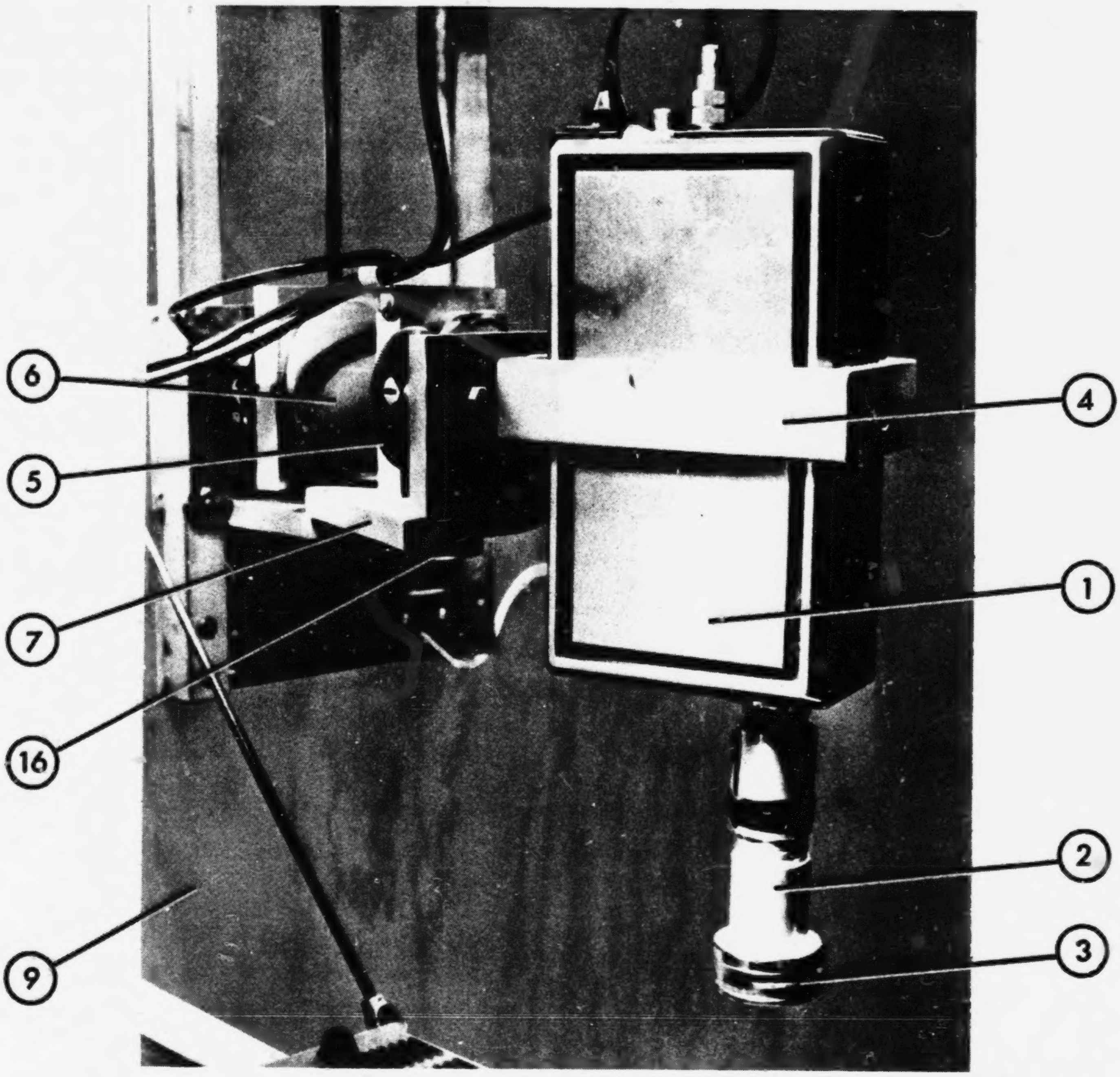


*Figure 4. Detail of Camera Assembly*

platform (11), which in turn is fastened to the upper ends of the vertical aluminum members (8). The user raises or lowers the camera (1) by a switch (12) that activates the motor (10). The camera (1) is rotated in a selected vertical plane by turning a knob (13) attached to a synchro transmitter (14), which is electrically connected to the synchro receiver (6). The knob (13) and synchro transmitter (14) may be placed at any convenient position on the horizontal wooden working surface (15). The vertical plane of rotation of the camera (1) may be changed by loosening the knob (16), turning the camera (1) through the desired angle and then retightening the knob (16). A Sony, TV5-305UW, television monitor (17) is mounted on an

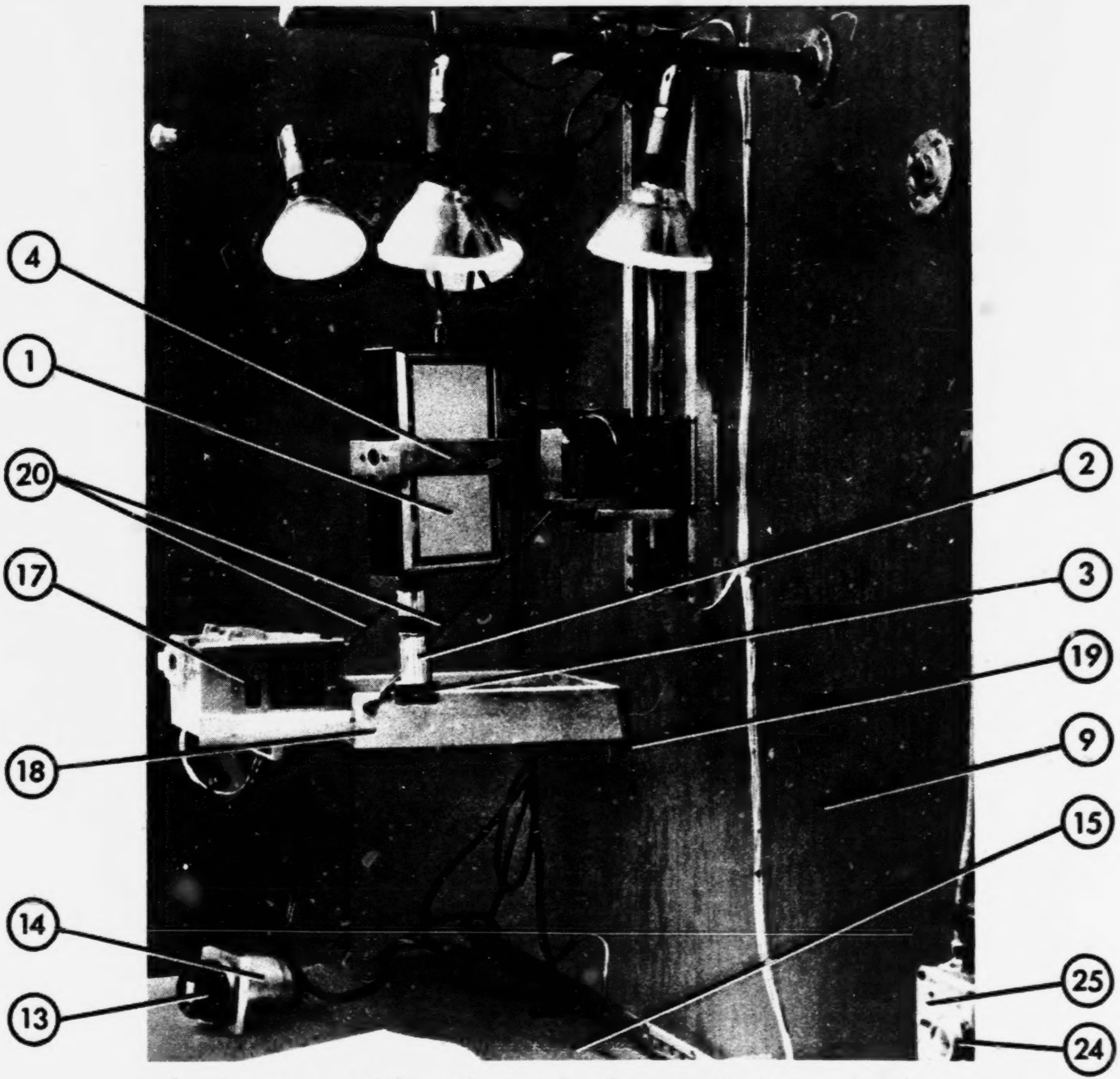


*Figure 5. Side View of the Prototype System*

extendable wooden shelf (18), which is attached to the wall through the wooden backing (9) by means of a hinge (19) and two turnbuckle adjustable rods (20). The extendable wooden shelf (18) permits the user to position the TV monitor (17) as close to his eyes as he finds comfortable. A small adjustment in the height of the TV monitor (17) can be effected by rotating the turnbuckles on each rod (20). Illumination of the working surface (15) is provided by four 130-watt spotlights (21) that are clamped to, but may be rotated about or moved along, two 20-inch rods (22), which are attached to flanges (23) that in turn are attached to the wall through the wooden backing (9). The intensity of the illumination provided by the spotlights (21) is controlled by a dimmer control circuit and switch (24). As it is currently wired, all electrical power for the system, with the exception of the spotlights (21), is controlled by a common switch (25).

### Key to Figures 3 Through 5

(1) TV Camera
(2) Variable-length lens adapter
(3) Lens
(4) Yoke
(5) Gear train
(6) Synchro receiver
(7) Aluminum housing
(8) Aluminum members
(9) Wooden backing
(10) Motor (raises and lowers camera)
(11) Horizontal platform
(12) Switch (controls camera height)
(13) Knob (activates synchro transmitter)
(14) Synchro transmitter
(15) Wooden working surface
(16) Knob (used in changing plane of camera rotation)
(17) TV monitor
(18) Wooden extendable shelf
(19) Hinge
(20) Turnbuckle adjustable rods
(21) Spotlights
(22) 20-inch rods
(23) Flanges
(24) Dimmer control circuit and switch
(25) Common or main power switch

## Appendix B

## OPERATION

The system is quite simple to operate. The user turns on the main power switch (25) and the dimmer switch (24), and then adjusts the intensity of the illumination on the working surface (15) by rotating the dimmer switch (24). He then adjusts the height of the shelf (18) supporting the TV monitor (17) by rotating the turnbuckles on the rods (20). If the system is used by only one user, this is generally a one-time adjustment.

The user slides the shelf (18) toward or away from himself in order to achieve a satisfactory eye to receiver distance. Writing or reading material is placed on the working surface (15) directly below the camera (1). Image clarity and the desired magnification are achieved by rotating the lower portion of the lens adapter (2) and by adjusting the height of the camera (1) using the switch (12). Image brightness and contrast are controlled by adjusting the appropriately marked knobs on the TV monitor (17). Using the knob (13) the user guides the camera (1) across the line he is reading or along the line upon which he is writing. Line advancement is accomplished by sliding the reading or writing material along and toward the rear of the working surface (15). Most people prefer to write with the writing paper inclined to the near edge of the desk or table. As this angle of inclination may vary from user to user, it may be necessary to adjust the plane in which the camera (1) rotates under the action of the synchro receiver (6). This is accomplished by loosening the knob (16), rotating the camera (1) through the desired angle and then retightening the knob (16).

If the illumination distribution on the working surface (15) needs to be altered, this can be accomplished by doing one or more of the following: rotating each of the spotlights (21) about the rods (22), shifting the position of the spotlights (21) along the rods (22), or altering the number of spotlights (21) per rod (22).

# TACTILE PERCEPTION

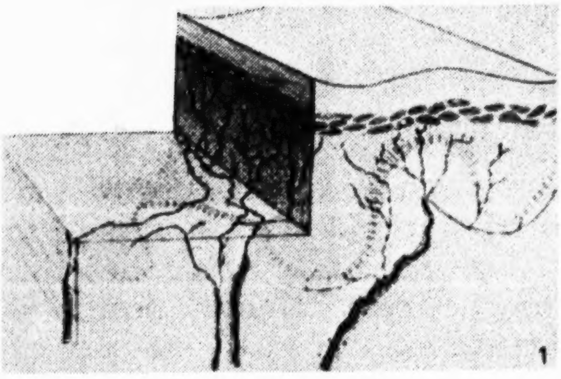
James C. Bliss and Hewitt D. Crane

All our knowledge about the world around us is based on information given by our five senses. Normally, most of this information is supplied by our eyes and ears. These sense organs have evolved into efficient receivers, capable of providing information to us at our highest comprehensible rates. Because of this, sight and hearing form the bases for vast industries such as telephone, television, and motion pictures.

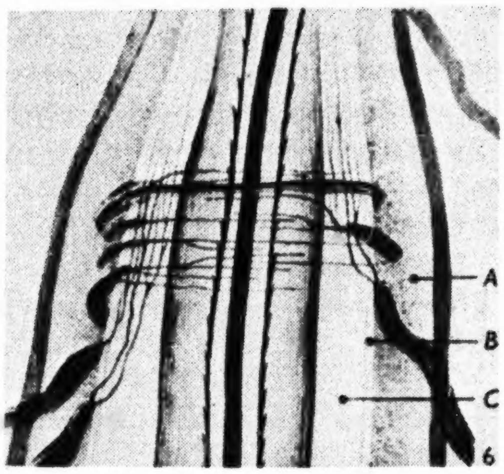
However, the tactile and kinesthetic senses are probably the most indispensable of our sensory systems, because they supply the feedback signals necessary for all of our controlled movements and muscular activity. The tactile sense responds to a wide range of stimuli, whether mechanical, thermal, electrical, or chemical. Information can be acquired by feel either actively, as when a blind person runs his fingers over the embossed dots of Braille print, or passively as when he senses the environmental temperature. Whereas the senses of sight, hearing, taste and smell are localized, the tactile sense is distributed over the entire surface of the body. Thus information can be presented at different locations on the body as well as at different instances in time. This versatility makes the tactile sense appear attractive for use as an additional communication channel in man-machine systems.

However, sensory-display devices that have attempted to substitute touch for sight or sound have been limited by a slow rate of information transmission to the individual. Whether this has been due to a fundamental limitation of the nervous system or to poor design of the sensory display has not always been clear. However, it is manifest that no device as yet has fully utilized all the informational capacity of the tactile sense.

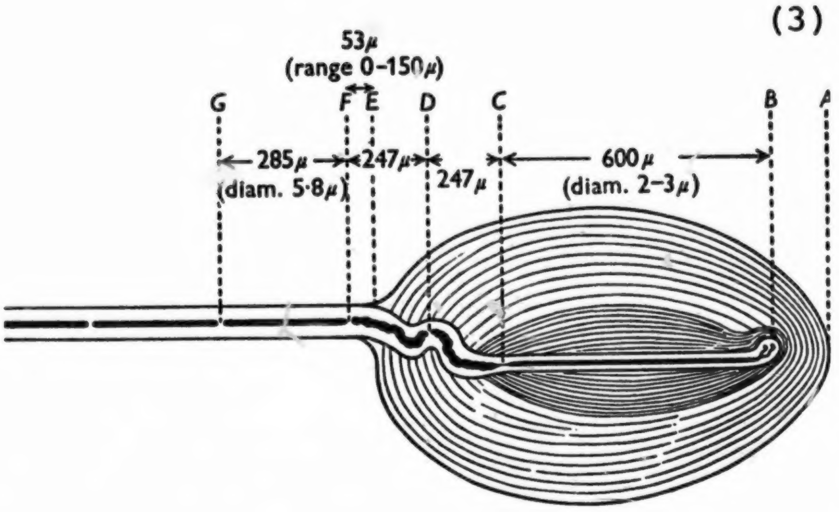
The skin is, from an evolutionary standpoint, the oldest of the sensitive tissues of the body. The skin layers are well innervated with a variety of neural structures (see box insert). Likewise many sensations, such as itch, contact, tickle, vibration, pressure, wetness, texture, electric shock, heat, warmth, cold, and pain can be elicited by skin stimulation. The complexities of this structure and these sensations offer many possible dimensions along which information can be coded. However, the best methods of information transmission by way of the tactile sense, and the limitations of this sense, must be determined before full utilization in practical communication systems is realized.



(1) Axons giving rise to fine, freely ending filaments which lie in between the epidermal cells. The filaments from neighboring fibers interdigitate and overlap with one another. (After Weddell, Pallie & Palmer.)



(2) Rabbit ear skin showing the manner in which myelinated nerves terminate within the tissues of a hair follicle. One set of stem nerve fibers give rise to arborizations of fine, freely ending filaments which encircle the hair and interdigitate with one another among the cells of the middle layer of the dermic coat. (After Weddell, Pallie & Palmer.)



(3) A schematic drawing of a typical Pacinian corpuscle. This type of ending is by far the largest and enjoys the unique distinction among end-organs of being identifiable by naked-eye inspection alone. The corpuscle consists essentially of a lamellated capsule, an extensive outer core or zone formed by alternating fluid-filled spaces and cellular lamelae, and a uniquely complex cellular inner core in which, situated axially, is a single unmyelinated nerve ending. (After Quilliam & Sato.)

*Figure A. Main Types of Nerve Endings in Skin*

# EXPERIMENTAL METHODS

Experiments on the information-handling capabilities of touch have generally been handicapped by lack of suitable stimulation techniques, certainly in comparison to experiments on vision and hearing. As late as the 1930s, experimenters in taction were using calibrated horse-hairs, dropped from measured heights, for stimulation. It has become apparent that more versatile tactile stimulators are required--stimulators small enough for large numbers of them to be stacked together in arrays. Complex spatial patterns could then be presented to the skin in various temporal sequences. For flexible control of such an array during an experiment, it is equally apparent that an on-line computer would be very convenient.

The experiments described here were performed with a computer-controlled facility in which tactile patterns on an 8-by-12 array (96 points) can be changed at rates up to 200 patterns (or frames) per second. These experiments are intended to determine characteristics of the tactile sense important to development of man-machine communication systems and to evaluate human capabilities in some specific tactile-communication situations.

Two kinds of tactile stimulators have been developed for use in these experiments: airjets (Fig. 1) and piezoelectric bimorph reeds (Fig. 2). Both produce sensations considerably above threshold. On the tasks described here essentially the same subject performance has been obtained with both kinds of stimulator. However, the airjet stimulators are more convenient in laboratory experiments because their spacing and frequency of oscillation can be easily changed. On the other hand, the piezoelectric bimorph reeds offer advantages in practical systems in that they require little power and space.

We have devised techniques for presenting patterns, which change in both time and space, on arrays of either of these tactile stimulators. To generate a pattern on the array, it is necessary to energize a selected set of stimulators for some time interval. A two-dimensional rectangular pattern can be thought of as a series of individual rows, each row being a one-dimensional pattern of on-and-off stimulators. In binary language, if an excited state is denoted by a binary 1 and an unexcited state by a binary 0, then the two-dimensional pattern is just a list of binary numbers, where the length of the list is equal to the number of rows in the pattern, and the number of binary positions is equal to the number of columns in the pattern. The computer used for these experiments operates on a word 12 binary digits wide, and it is for this reason that we have typically used a

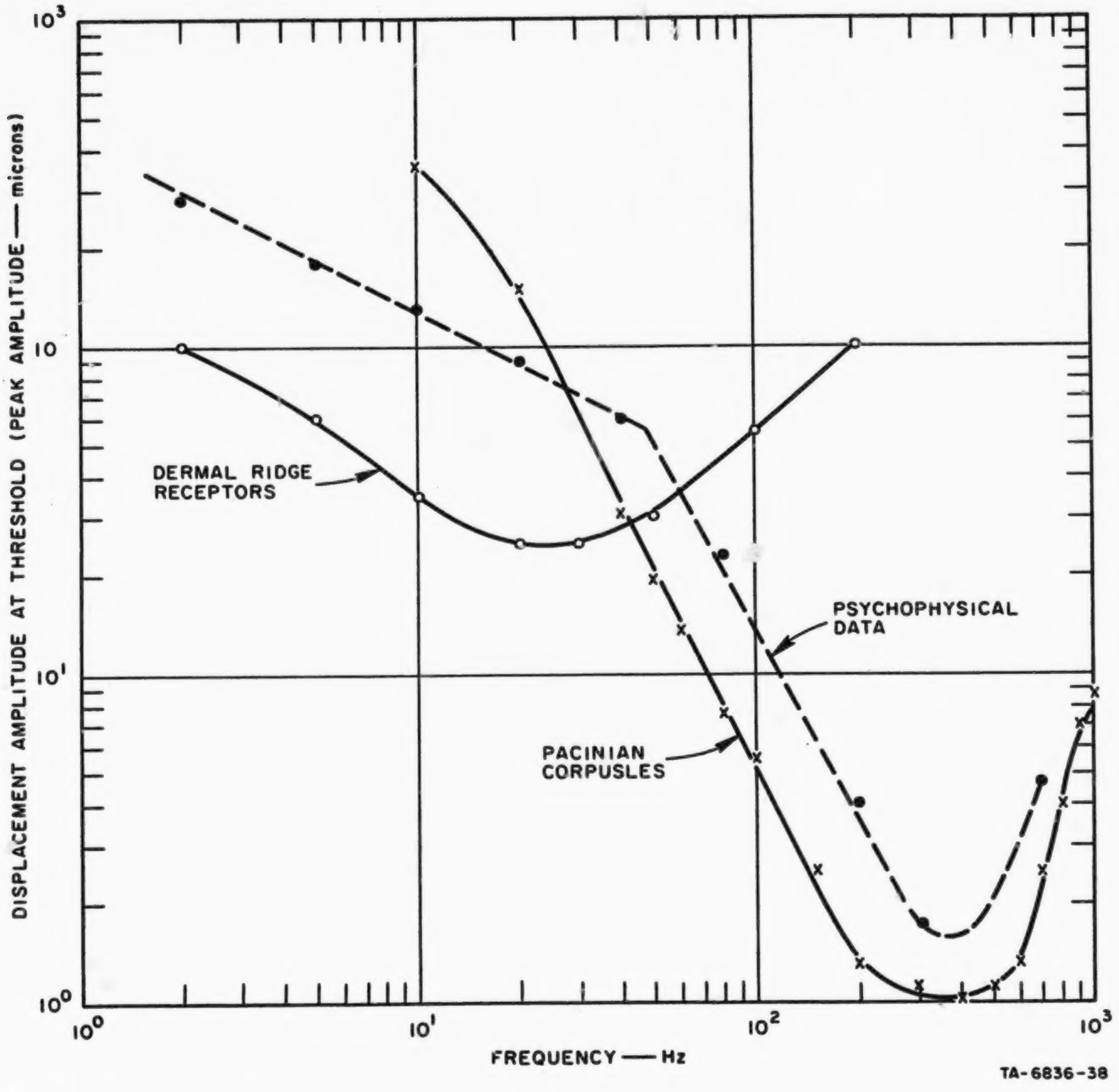


*Figure B. The dermal ridge receptors presumably account for the human threshold at frequencies below 40 cycles per second while the Pacinian corpuscles account for the threshold curve at higher frequencies (schematic representation after Mountcastle).*

## Tactile Neurology

*The peripheral nerve fibers for the sense of touch pass from the spinal cord to the layers of the skin. They are sometimes myelinated and near their endings often give rise to profuse arborizations of fine naked filaments, or dendrites, which branch toward the skin surface. The dendritic trees from neighboring nerve fibers overlap and interdigitate extensively with one another. Most authorities agree that in mammalian skin nerve fibers terminate in one of three main types of end formations (Figure A): (1) unencapsulated or free nerve endings, (2) nerves ending in relation to hairs, and (3) encapsulated nerve endings such as the Pacinian corpuscle. The density of nerve endings on the fingertip is over 100/sq mm and over the entire body the density is so great that a discrete pinprick will always activate more than one ending.*

*It was once thought that the many anatomically observed different nerve endings in skin gave rise to different tactile sensations, such as touch, heat, cold, itch, and so forth, each type of ending being sensitive only to a particular type of stimulation. However, this view is no longer held by many authorities. Recent evidence suggests instead that many endings are sensitive to several types of stimulation.*

*Related to the type of stimulation used in the experiments described in this article, the neurological evidence suggests that for glabrous skin, such as the palm of the hand and sole of the foot, there are two functionally different tactile systems. One of these is connected to endings in the dermal ridges and is most sensitive at relatively low frequencies of vibration, as shown in Figure B. This neural system accounts for the human threshold at low frequencies up to about 40 hz. The other system is connected to Pacinian corpuscles which are found in deep tissue. This receptor is extremely sensitive at frequencies in the range 100 to 300 hz and accounts for the human threshold at high frequencies of vibration.*

*Subjects report that the sensation at low frequencies of vibration is localized to the skin at the site stimulated. In contrast, at high frequencies a sensation is reported of vibratory hum, from deep within the skin, and spread so that it cannot be localized accurately. Thus one system seems to be a low temporal frequency, high spatial resolution system while the other seems to be a high temporal frequency, low spatial resolution system.*

*Similarly, there are also two general systems of nerves running up the spinal cord to the brain subserving touch. One system, called the lemniscal system, seems to be tuned for discriminatory functions as precise as known in nature. Certain properties of this system endow it with exquisite and precise capacity to present neural transforms at higher levels of the brain concerning the position, form or contour, and change with time of the peripheral stimulus. The second system is called the spinothalamic system and seems to be concerned with much more general aspects of sensation and to transmit information concerning the qualitative nature of peripheral events, rather than place, pattern, or temporal cadence. How these systems work together to produce subjective perceptions is not understood.*

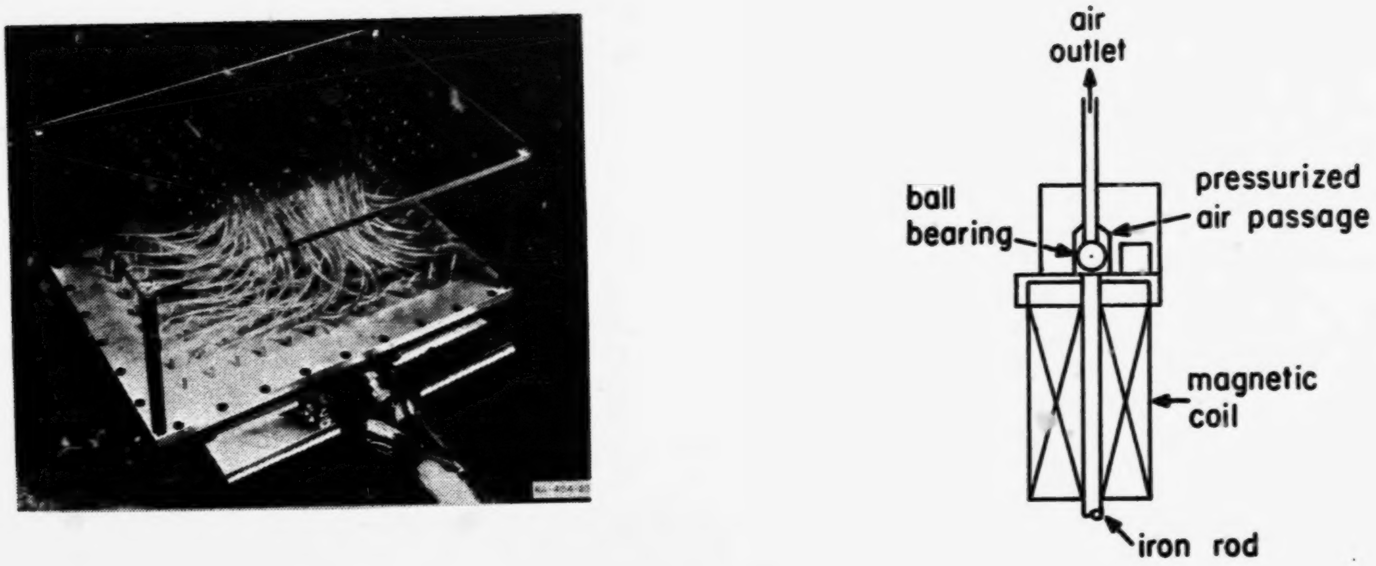


*Figure 1.* Airjet stimulator array (A) combines a number of electrically controlled high-speed valves (B). The basic valve uses a steel ball bearing that moves away from the outlet port when the electromagnet is switched on by the computer. This movement opens the valve, permitting air to flow through the output tube. When the magnet is switched off, the air pressure moves the ball back against the output tube, thereby closing the valve. These valves deliver pulses of air that rise to their full output in less than a ms, remain at full output for as little as half a ms, and shut off in another ms. These short bursts of air are easily conducted for a foot or so through flexible plastic tubes.

display 12 positions wide. An 8-by-12 pattern consists then of eight such 12-bit words.

To operate the display, electronics circuits were built that can store the series of eight computer words and modulate the appropriate stimulators at an adjustable frequency. The basic idea is to store a set of patterns--such as letters or "pictures"--in the computer. We can then call for these patterns in any desired order. The patterns can be called one at a time from a typewriter, or in a predetermined series that is stored in the computer. Often the computer itself is used for organizing and analyzing the data. A typical experiment might involve a subject identifying each of a long series of patterns. After presentation of a pattern, the experimenter uses the typewriter to enter the subject's response--such as the name of a letter--into the computer. After storing this result for further analysis, the computer automatically presents the next pattern of the list.

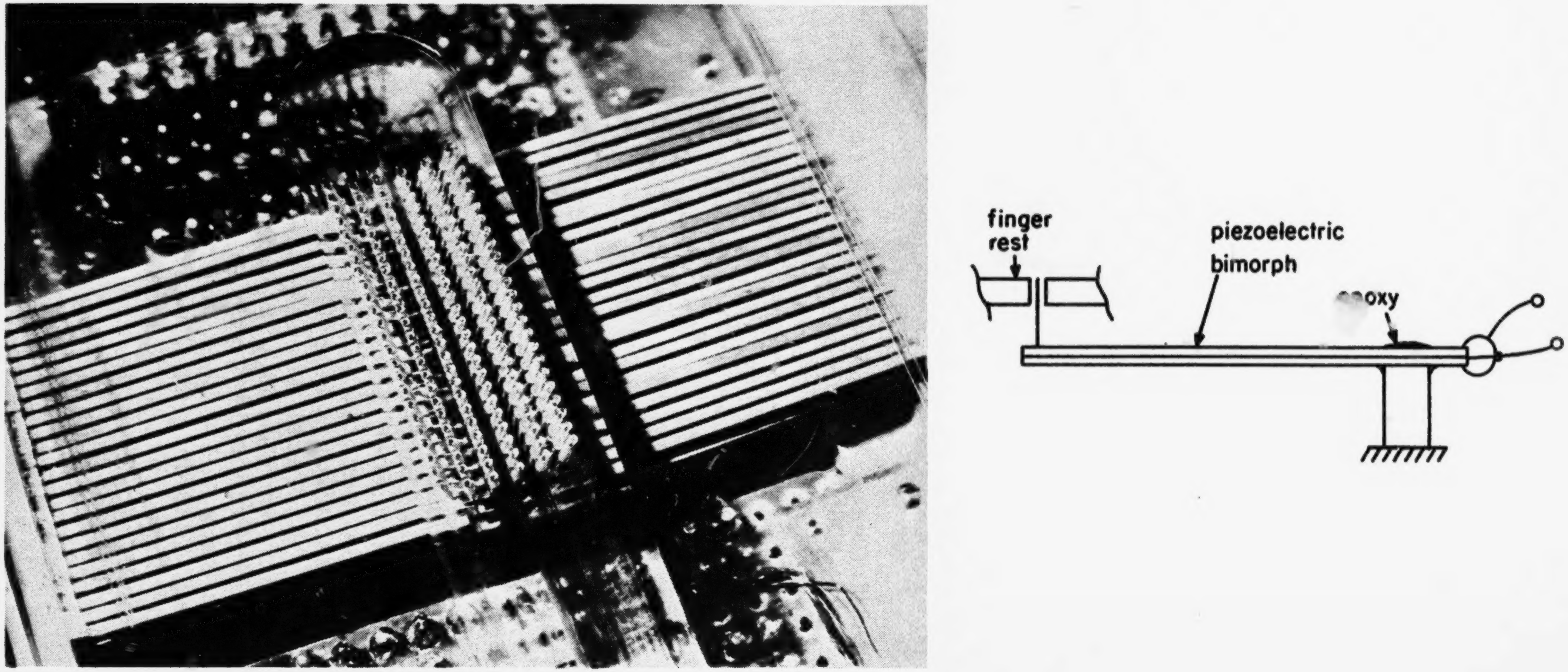


*Figure 2*. Piezoelectric stimulator array (A) is constructed by cantilevering bimorph reeds and attaching a vertical pin to the free end of the reed (B). The bimorph reed consists of two oppositely polarized strips of lead zirconate that are bonded together. When voltage is applied, one strip tends to expand and the other to contract, with the result that the bonded pair of strips bends. The pin protrudes through a hole in the rest plate, imparting both a normal and tangential force to the skin. As little as 10 millionths of a watt of power applied to one of these devices produces a noticeable sensation.

## THE TACTILE EXPERIMENTS

Initially various experiments were tried involving tactile illusions, such as the perception of apparent tactile movement patterns. It became apparent that even with a small amount of training, quite complex spatial-temporal patterns could be readily perceived. One thing was clear: an understanding of tactile perception was not something to be accomplished in any single bold step. Indeed, visual and auditory experiments have been extensively conducted over many decades with no apparent end. It was therefore not initially a matter of designing crucial experiments, but rather of conducting quantitatively reproducible experiments that might give some idea of the information-handling characteristics of the tactile perception system. For this reason, we launched initially into experiments involving the reading of English letters and text. We have since backtracked to more basic experiments in which we are attempting to isolate some of the more fundamental perceptual phenomena.

### Tactile Reading

In the initial reading experiments airjets were spaced on 1/4-inch centers so that the 8-by-12 display just about covered the entire area of the four fingers. At that time, we had one blind subject and a few with normal eyesight. With capital English letters designed on a 5-by-7 matrix (Fig. 3), the sighted subjects had difficulty identifying single letters presented in what we called the "frame mode" where the entire pattern was presented simultaneously for, say, a third or half of a second. The blind subject, however, who read braille very well but previously did not know the English alphabet (by letter shape) at all, had relatively little difficulty. In our first experiments, then, we gave the blind subject the regular English alphabet, and with the sighted subjects we attempted to design a special alphabet that could be read with relative ease (Fig. 3).

It was supposed, and subsequently shown, that if the computer is programmed to move the letter under the finger, perception is stronger and clearer than for a stationary presentation of the letter. Hence, we adopted a display mode similar to that used in electric signboards where the letters are made to flow across the display. At first we let single letters move across the display, with increased practice we packed letters closer and closer until eventually only a single empty column remained between letters. In this way we were easily able to train several blind readers, in a matter of a few dozen sessions, to read English text at rates of 30 words/min. One achieved a rate approaching 40 words/min.

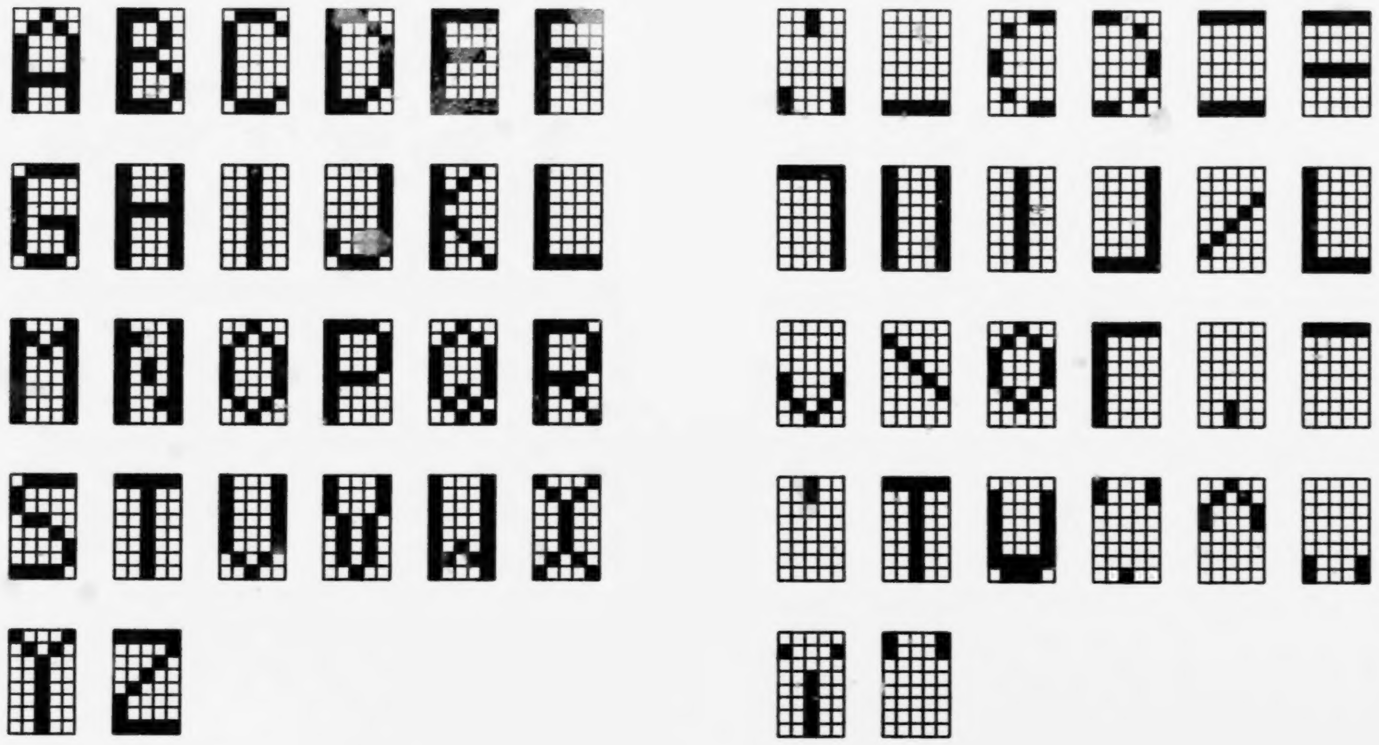


*Figure 3.* Block letter alphabet (A) was taught to blind subjects who eventually learned to recognize the shapes rapidly with a high accuracy. Reading rates of over 30 correct words per minute were obtained with a fixed-speed "moving-belt" type of display.

Simplified letters (B) are easier to distinguish tactually than the block letters, and can be learned quickly because of certain key similarities to the block letters.

To understand the complexity of the spatial-temporal pattern in this experiment, consider the operation of the display at 30 words/min. Assuming 5 letters and 1 space per word, then 30 words/min implies 3 characters/sec, or 18 frames/sec with each character being 6 frames wide. While each single frame is displayed the airjet stimulators that are "on" actually pulsate at a relatively high frequency, typically about 200 hz. Thus, each pattern remains on for about 50 ms and during that time each excited stimulator pulsates about 10 times. All of the stimulators pulsate in unison. (When the display operating at this speed is presented to a person for the first time, he finds it difficult to believe that any one could learn to read it at all.)

## A Reader for the Blind

These tests actually became a simulation of a reading machine for the blind. Technology has reached the point where it is possible to blind a small hand-held optical scanner that can convert a visual picture into an analogous tactile picture. With such a device the subject himself can scan the printed page, and have the portion of the text under the viewer at any instant converted into a kind of vibratory tactile reproduction. Although it was clear that such a device could be built, the first model would nevertheless be relatively costly, and furthermore many design questions are still unanswered. It was, therefore, of interest to use our experimental facility to simulate the scanner. Rather than having the subject himself scan a printed line of text, we stored the text in the machine and presented it to him as it would have appeared had he scanned the line at some predetermined velocity.

The results of the reading experiments described above were sufficiently encouraging that a serious effort is now under way to build such a optical-to-tactile image converter using piezoelectric bimorph reeds. An initial prototype device is shown in Figure 4. This device generates a tactile facsimile of ordinary printed material that the blind reader can sense with his finger. An array of reeds vibrate through perforations in a sensing plate on which the blind reader places a finger. The reeds are controlled on a one-to-one basis by an array of phototransistors on which an image of the printed material is focused. In laboratory trials with this device, subjects have read at rates approaching 20 words per minute. However, this reader is still in the experimental stage with newer models planned to overcome shortcomings revealed in initial tests. If the subsequent tests are successful, it will at best be several years before such devices could be generally available.

An important result of the computer simulation of this optical-to-tactile image converter was the effect of varying the display width. With the amount of training our subjects have had thus far, they have preferred to use only the tip of the index finger, which covers only three or four columns of the display. But the number of columns in actual operation can be easily altered. This corresponds to changing the width of a visual reading "window."

The effect on performance of varying window widths is shown in Figure 5. The change from four to three columns is insignificant, but below three columns the reading accuracy drops sharply. With only one column, the subject tends to lose any sense of a moving two-dimensional pattern. Points simply swing back and forth vertically with great loss in two dimensionality.

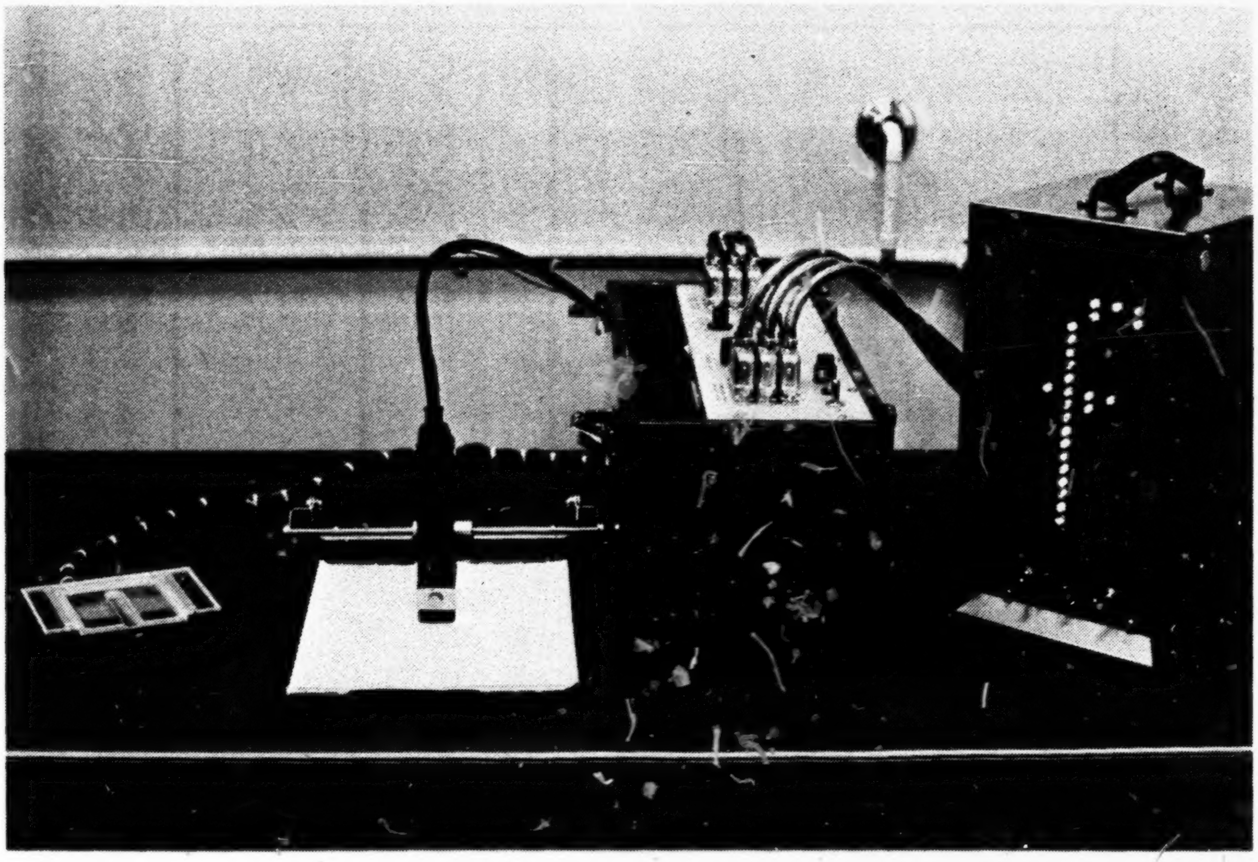


*Figure 4. Reading Aid Used to Test Engineering Design.* As the subject moves the probe (left center) across the printed page, images of the print are transmitted to the 24-by-6 photocell array by means of an aligned plastic fiber optic bundle. The photocell signals are used to drive circuits which activate tactile stimulators (far left) and lights (far right) in corresponding 24-by-6 arrays.

## Design of a Tactile Alphabet

Initially the sighted subjects report that the block-letter alphabet was confusing. They said the display felt like a blast of air with little pattern. We altered the alphabet shapes to determine if readability could be significantly increased. The approach in redesigning the shapes was to change the characters as little as possible--so as to minimize relearning time--but to trim them down by abstracting their shapes. The resulting letter shapes are shown in Figure 3, grouped in terms of different line and curve types. A naive subject learns these patterns relatively quickly and with high accuracy.

In this series of tests we found the spacing between the airjets of the array not critical. Cutting the spacing in half, for example, to 1/8-in. between jets, led to comparably good results. In fact, packing the tubes as closely as possible, with a resulting 1/16-in. spacing, also led to good results with the display now fitting a single fingertip.

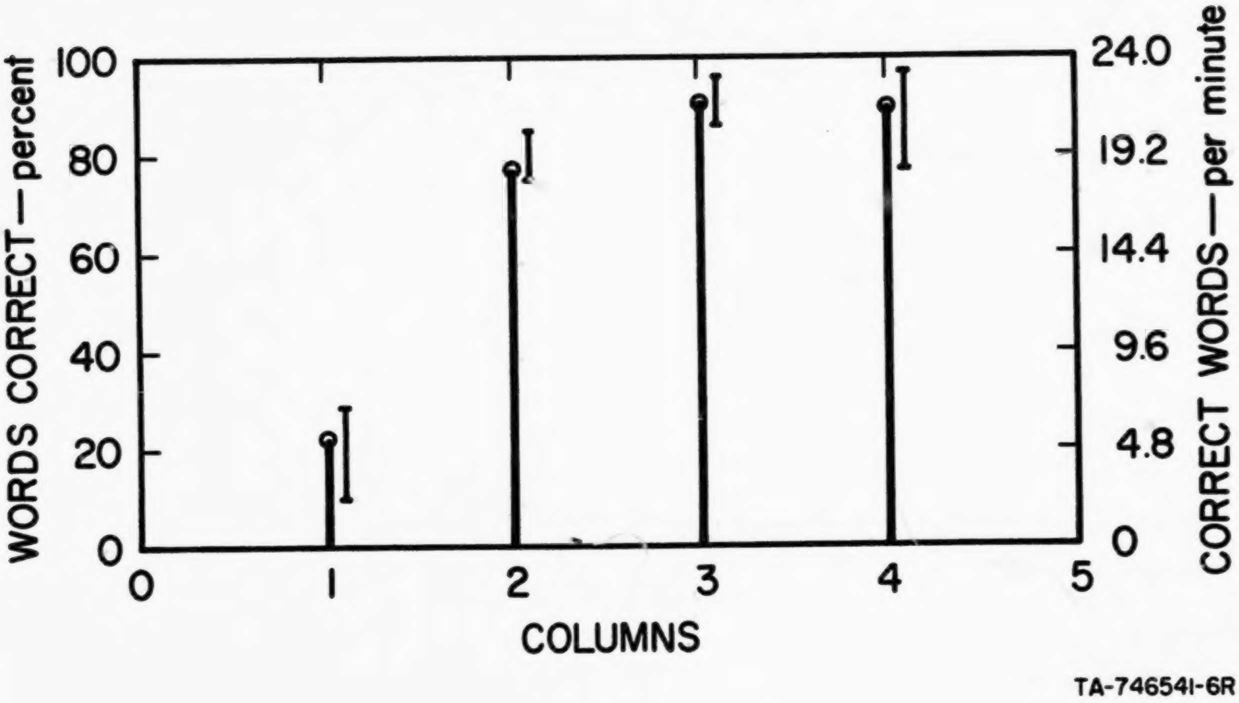


*Figure 5*. The accuracy of reading with a "moving-belt" of block letters presented tactually decreased greatly when the width of the display was decreased below three columns.

## Conditions for Good Tactile Letter Recognition

We had observed that significant improvement was obtained when a character was made to move across the fingers. In one series of experiments a different method of movement was tried, namely, the entire display was rotated slightly so that each jet traveled in a closed circular locus (Fig. 6). This type of movement significantly improved recognition performance.

The optimum frequency and amplitude are, in general, inversely related. The larger the amplitude of rotation the lower the optimum frequency. With an amplitude of rotation of about 1 cm, for example, the optimum frequency is about 7 rotation cycles/sec, or about 150 ms/rotation. At this rotation rate, the display makes two complete rotations during a 0.3-sec presentation. With an air-pulse rate of 200 hz, or a pulse every 5 ms, there are 60 pulses from each excited jet during the presentation, or 30 pulses/rotation cycle, spaced every 12 deg around the circular locus.

Looking in detail at what happens on the skin from a rotating, pulsating display, we see that the events are quite complex, especially since a single-point stimulator produces traveling waves of skin movement that persist for a large distance from the site of stimulation. Nevertheless, the rotation leads not only to an improved subjective feeling

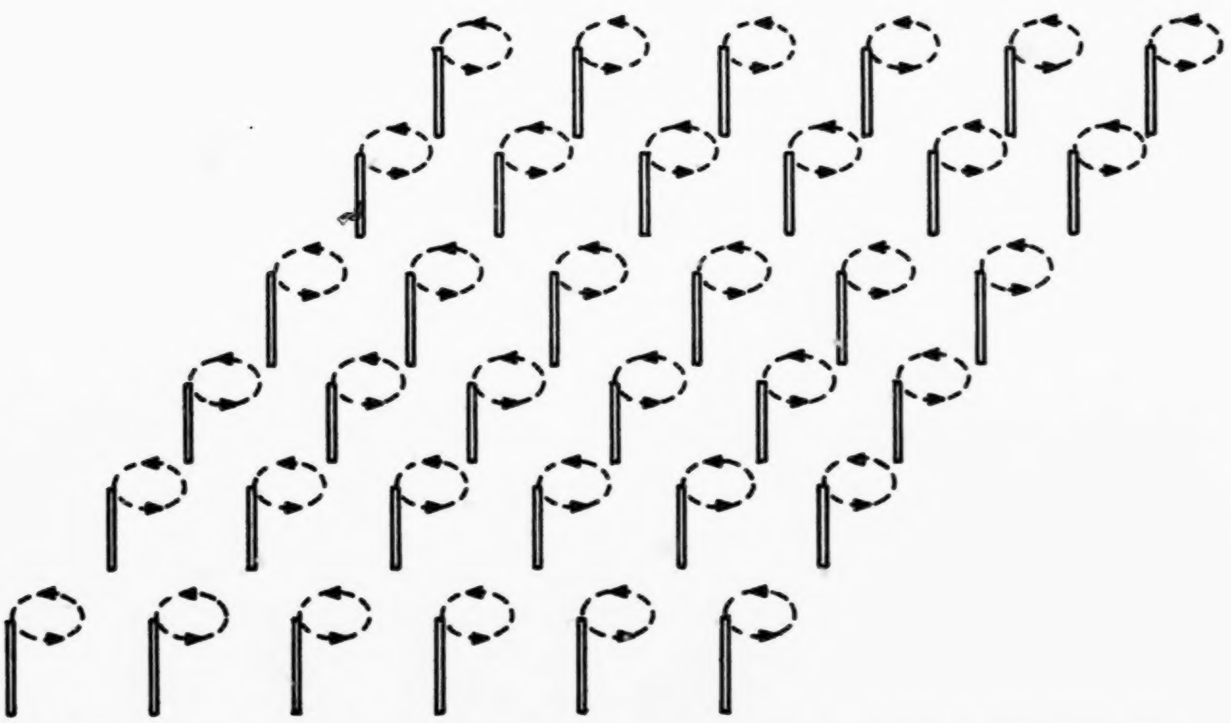


*Figure 6.* Better performance on a pattern recognition task was obtained when the entire array of airjet stimulators was rotated as shown so that each airjet in the array moved about a small circle.

about the quality of the display but also to quantitative improvement in scoring accuracy. We were led to this type of test by considering the somewhat analogous visual experiment in which one views a visual pattern through a shattered piece of glass. When the glass is shaken back and forth over the pattern, the otherwise highly fragmented pattern is greatly smoothed and perception vastly improved. We felt that the multiple finger surfaces involved here, and also the relatively large receptive fields of the peripheral nerves with respect to interjet spacing, might have an effect somewhat similar to the shattered glass which tends to break up the pattern. Our results support this hypothesis.

Another finding from our research has been the temporal interaction of letter patterns presented one after the other at the same location. As subjects became highly practiced, the rate of presentation of letters can be made sufficiently high that response time becomes a problem. With 0.3-sec letters presented every 0.9 sec, for example, the subject could not respond without his response interfering with the next arriving letter. We thought that it might help to pack the letters in close triplets, that is, three 0.3-sec letters in the first 0.9 sec, followed by a 1.8-sec period to respond, so that the average rate would still be the same. What we found, instead, was that the central letter was so masked by the adjacent letters of each triplet that it was practically imperceptible.

This led to some studies on temporal interaction on which just two characters, each with duration *A*, were presented on the airjet array with an interval between characters of *B*. For small values of *A*, the second letter tended to mask the first (Fig. 7) causing the subject to make more errors on the first letter. However, for large values of *A*, the first letter tended to mask the second, causing the subject to make more errors on the second letter. Also, letter reversals began to show up at the smaller values of duration and interletter spacing, especially when *A* + *B* was less than 0.1 sec; that is, the subject would respond with the correct letter pair but in the wrong order.

## Time Course of Perception

While the picture is far from complete, many investigators have suggested models of perception based on input quantization of time. For example, according to one model, at least three intervals are involved in the process of intake of information by a human: (*1*) a read-in or summation interval of 50 to 100 ms; (*2*) an interval immediately after (*1*), in which a second stimulus may tend to replace a first stimulus; and (*3*) a later interval of little interference. In terms of such a model, whether there should be more first- or second-response errors in the experiment with two letters is determined by which interval is involved. According to this interpretation, then, when the second letter occurs immediately after the read-in time, the first letter may tend to be cancelled or replaced, thereby producing more first-response errors. With further temporal separation, the first letter is safely tucked away in immediate memory before the second letter is presented, thereby reducing the first-response errors.

The development and verification of this kind of information processing model of the human has been one of our objectives. By understanding how the human acquires and processes information using the tactile sense, we should be in a better position to design devices to utilize these capabilities.

## Tactile and Visual Memory Models

Of special interest was an evaluation of whether we could verify a model (Fig. 8) for tactile perception and human memory consisting of several interacting parts, similar to that being developed for vision. For example, according to one of these visual models, the memory system is divided into three components: a sensory register, a short-term store, and a long-term store. These separate memory components are presumed to interact in the information acquisition process

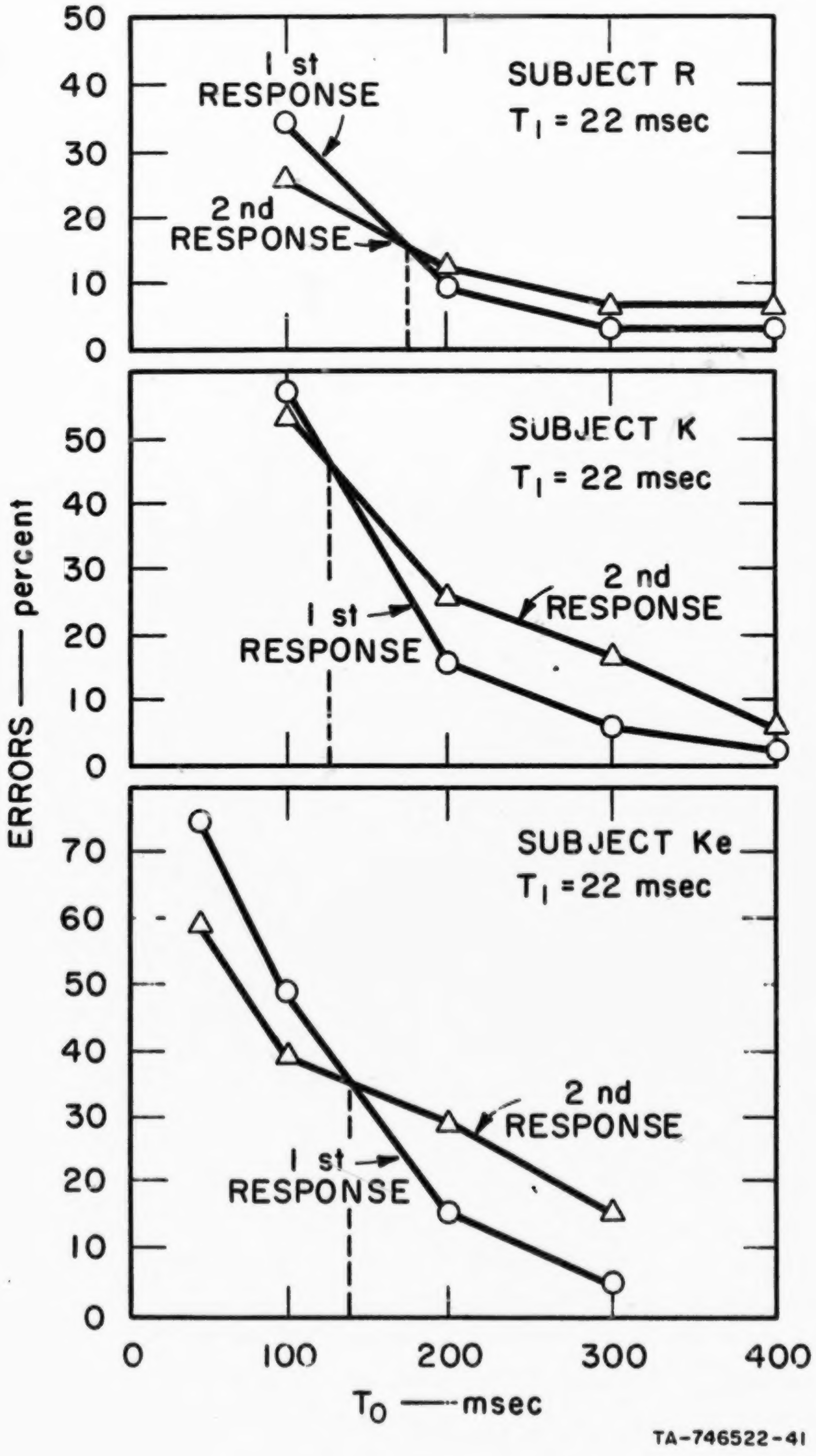


*Figure 7*. When two tactile-letter patterns are presented at the same anatomical location, with a 22 ms dead time between them, interaction produces response errors, especially when the stimulus on time ($T_0$) is short. When the stimulus on time is less than about 150 ms there are more first-response errors than second-response errors, indicating stronger backward masking. For $T_0$ greater than 150 ms, there are more second-response errors, indicating stronger forward masking.

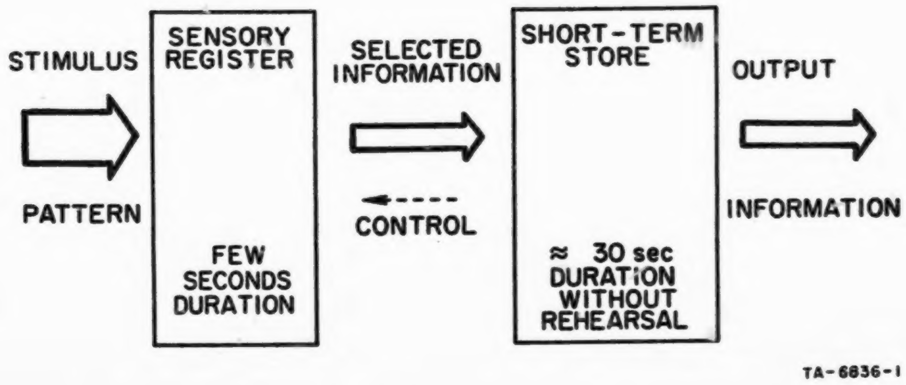


*Figure 8. Model for Tactile Memory Tasks.* An imperfect image of a briefly presented tactile pattern is presumed to be stored in the sensory register. The desired information from this image is extracted and transferred to the short-term store, within the limitations of the decay rate of the sensory register, the scan rate, and the capacity of the short-term store.

according to the intervals described above. In other words, information is read into the sensory register in the first interval of 50 to 100 ms. It is then processed and read out into a short-term store. Next it may or may not be transferred to the long-term store or permanent memory. In this case of visual stimuli it has been shown that (*1*) the sensory register has a strong capacity at least several times greater than the capacity of the short-term store, which may be as small as only four or five items, and (*2*) information in the sensory register decays within a few seconds. The mechanism for the sensory register may actually be persistence of vision or visual after-images.

The basic visual data, which is explained in terms of such a model, is of the following form. Consider a short-flash (tachistoscopic) presentation of a field of random letters, for example, three rows of six letters each. If the subject is asked to recall all of the letters seen (called a "whole report"), then on the average he can correctly identify only four or five letters. But, if before the response a special marker is used to identify some triplet of letters in the field that the subject must name, then his response on this subset is near perfect. This result has been interpreted to mean that all the letters were actually "available" to the subject, even after the stimulus terminated, and that in the whole-report experiment some other process set the upper limit of only four or five letters correct. The presumption is that there is a very short-term memory, or sensory register, that stores the input pattern pictorially, or eidetically, followed by an immediate memory of limited capacity, which does not store pictorially, but in processed "chunks" of information. Thus, in the whole-report experiment, the output is limited by the four or five chunk capacity of the immediate memory, but the marker experiment (referred to as a "partial-report" experiment) does not tax the immediate memory capacity and the measured percentage correct gives an estimate of the storage capacity of the sensory register. By determining the decrease in response accuracy with increase in time between the end of the pattern presentation and the appearance of the marker, this visual sensory register is found to have duration of a few seconds.

It was thought that the following experiment might determine whether the tactile system is similar, and might also give some basic data on spatial-temporal interaction of tactile stimuli. The 24 interjoint regions (phalanxes) on the palm side of the fingers of both hands (thumbs excluded) represent the tactile space. A special apparatus was designed to hold 24 individually adjustable airjets. Each phalanx was labeled with a letter of the alphabet as shown in Figure 9. The whole-report paradigm was to present *N* simultaneous stimuli (where *N* ranged from 1 to 12) and to have the subject identify as many positions stimulated as possible. This arrangement lends itself to partial-report experiments, where the subject is asked to name the stimuli only in some limited region, for example, the tips of the fingers. A visual or auditory marker was used to indicate the region that the subject was to report.

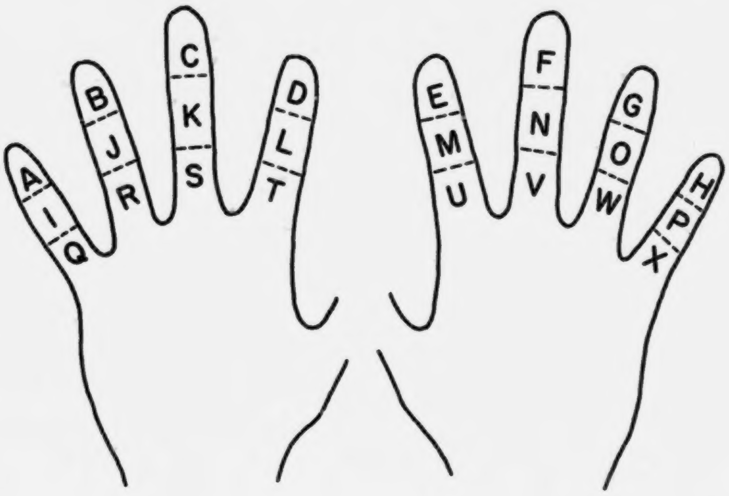


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*Figure 9.* Labelling of the 24 interjoint finger regions (phalanges) for the multiple point stimulation experiment.

We entered this study with some uncertainty because of older reports of great masking between fingers. We found immediately that subjects could score almost perfectly when $N = 1$, and were indeed surprised at the very high error rates when $N = 2$ on only one hand. With any two positions simultaneously stimulated--out of a field of 12 possible positions (that is, one hand)--there was an initial error rate of better than 30 percent.

It seemed as though earlier reports of large masking might indeed be correct. However, we soon found that the error rate fell almost to zero in the course of only a few one-hour sessions. Apparently, the older experiments were not conducted long enough to show that the large masking was largely a transient effect, and that a learning process is involved. With the earlier experimental techniques it was of course generally difficult and awkward to conduct an extended series of reproducible experiments of this type.

For most subjects, the $N = 2$ experiments were initially conducted on just one hand. After a few training sessions, when errors dropped to very small values, we switched to the other hand for the first time and found that the initial rate of errors was much lower than the initial rate on the first hand, as though there was a significant "transfer" of training from one hand to the other.

We then designed an experiment in which the number of simultaneously activated stimulators was systematically varied from two to twelve. Early in these experiments it became clear that widely different levels of performance could be obtained from different subjects, perhaps because of differences in training or development of the sense of touch.

To obtain some idea of the range of performance possible, and yet use only a small number of subjects, we selected our subjects in a special way. Preliminary results from a standard echo-detection test conducted by Charles E. Rice of the SRI Biosonar Laboratory indicated that the performance of a group of five early blind subjects (blindness occurring before the age of two) was superior to the performance of a group of six late blind subjects. We selected a subject from the late blind and a subject from the early blind groups used by Rice for our tactile experiment. Obviously, with only two subjects conclusions regarding the effects of blindness could not be obtained. But since the memory of blind persons is almost legendary, we felt that an experiment that measured properties of the memory system would be particularly sensitive to any differences among these subjects.

In these experiments, in which between 2 and 12 interjoint regions of the fingers were stimulated, we wished to obtain information on several aspects of our tactile memory model. First we wished to determine the storage capacity of the immediate memory with tactile stimuli. Next we wished to determine whether or not the tactile sense has a sensory register similar to that found in vision and, if so, what its storage capacity and time duration is. Finally, we wished to know what kinds of errors were most likely, that is, whether a stimulus at one location would be likely to be mistakenly perceived at another location.

The answers to these questions are indicated by the results shown in Figures 10, 11, and 12. The data from four of our subjects, three sighted and one late blind, were remarkably similar so we have averaged their curves together. Since the early blind subject performed significantly better, his data are shown separately. All the data are corrected for guessing, so that only estimates of points actually perceived are given.

The whole report curves (Fig. 10) indicate a span of immediate memory of about four stimulus positions out of twelve for the four similar subjects and almost eight positions out of twelve for the early blind subject. The shape of these

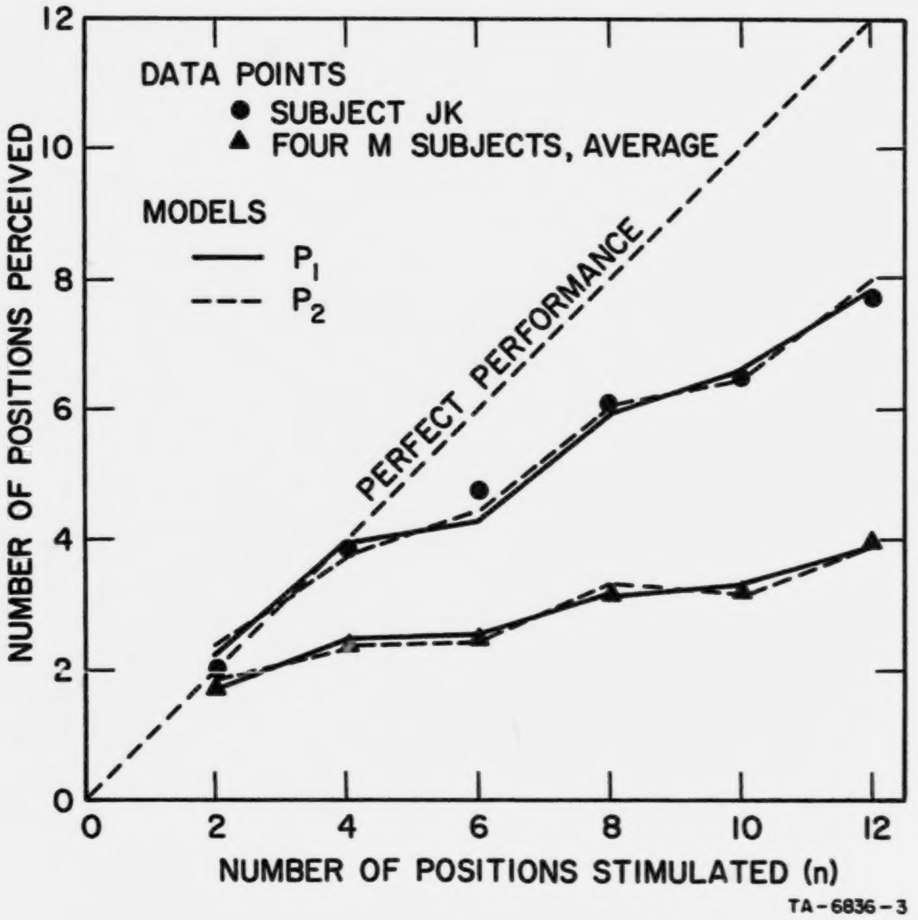

*Figure 10.* Estimated number of points perceived as a function of the number of points stimulated in the whole report experiment. The estimated number of points perceived is derived from the response accuracy of making allowance for guessing.

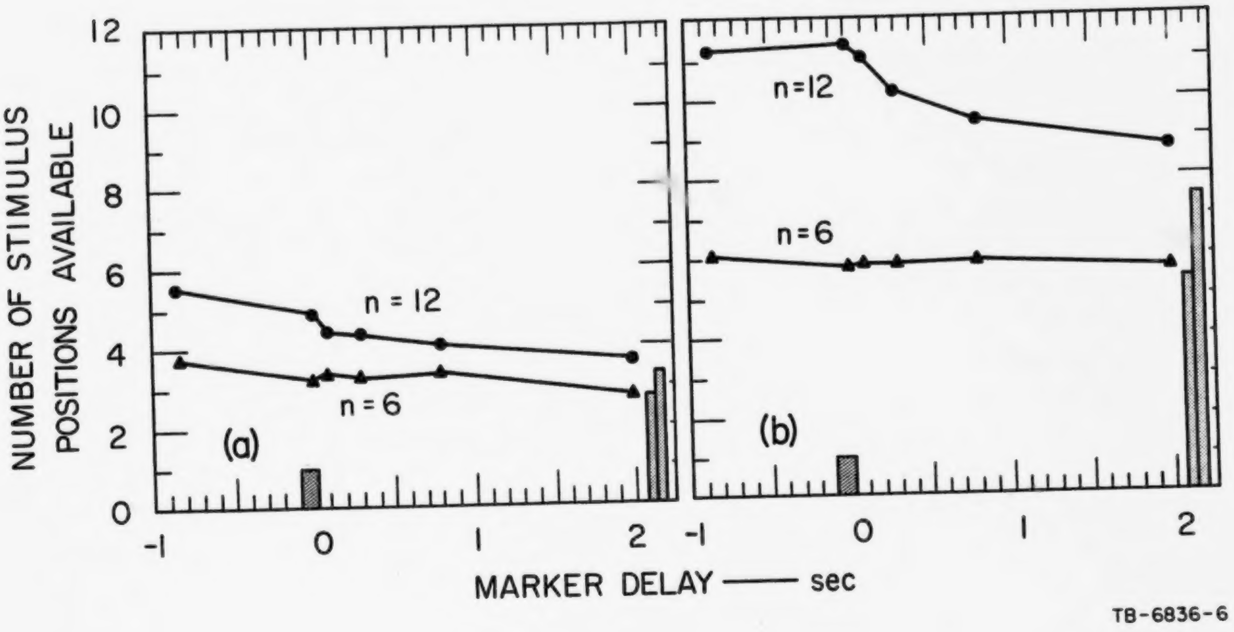

*Figure 11.* The number of positions available to (a) the four average subjects, and (b) the early blind subject as a function of marker delay indicates that the storage capacity of the sensory register is about 50 percent greater than that of the short-term store and that the information in the sensory register decays to about 30 percent of its initial value in 1.3 sec. The cross-hatched bar represents the timing of the stimulus and the solid bars represent the whole report from the partial-report patterns.

curves differ markedly from the corresponding visual curves, which follow the perfect line for four or fewer stimuli and then flatten off abruptly at a constant value of 4.5 items correctly named.

The partial report curves (Fig. 11) indicate that a tactile sensory register indeed exists. It has a storage capacity that is about 50 percent greater than the capacity of the short-term store, or immediate memory, and it decays exponentially with a time constant of about 1.3 sec. This storage capacity is less than and the duration is shorter than the analogous visual sensory register.

Our third question, that of spatial confusions, is answered by the results of an analysis of this data performed by one of our colleagues, Dr. John W. Hill. This analysis indicated that locations separated by three or more finger phalanx positions were not confused significantly often and that when subjects made location mistakes, they most frequently made responses in the immediate neighborhood of a stimulus. Thus, Figure 12 shows the most likely confusions made by the subjects. Note the greater number of left-right confusions made by the four similar subjects compared with the number made by the early blind subject. For all subjects there were significant confusions in the direction from the periphery of the area stimulated on each hand toward the center of this area. Also, there were more confusions along a finger than between fingers and confusions between hands were few. Thus these data indicate that the tactile sensory register is limited by spatial confusions or from resolution, and this limitation characteristically causes certain types of errors to be more likely than others.

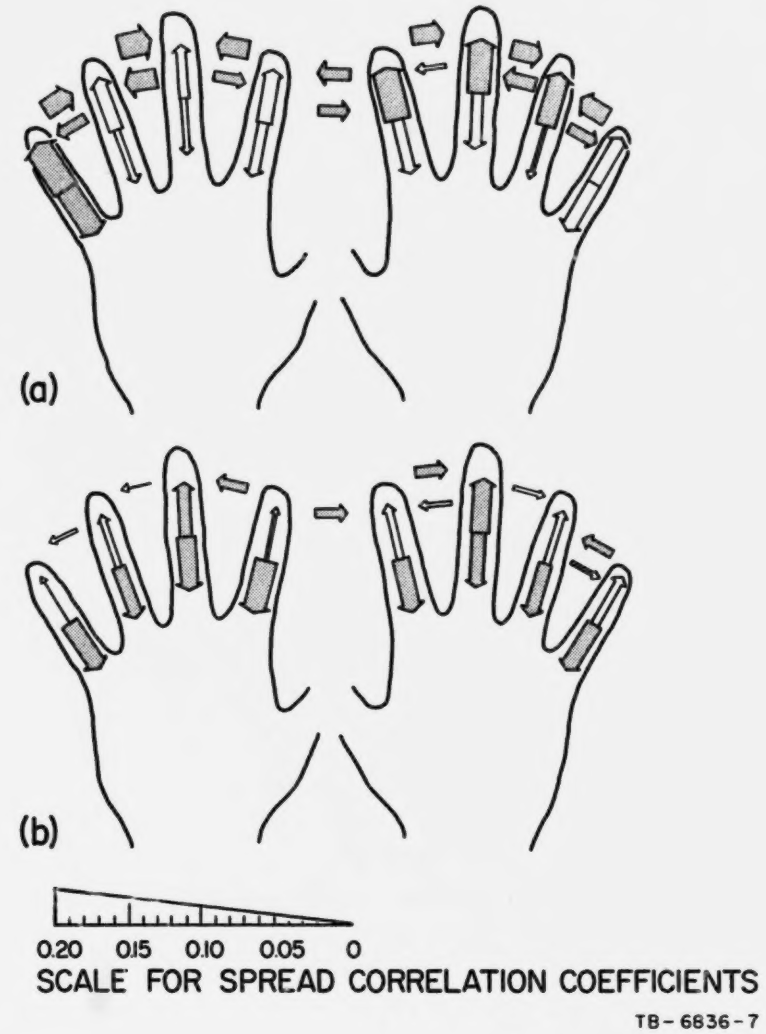

*Figure 12. Confusions Made by (A) The Four Subjects, and (B) the Early Blind Subject in the Whole Report.* The width of the arrows is proportional to the confusion between fingers and phalanges. Dark arrows represent confusions significantly greater than zero (5 percent *t*-test), while open arrows represent non-significant confusions.

## Manual Control with Tactile Displays

Our on-line computer facility has also permitted us to study manual control with tactile displays and to apply a technique, commonly used by servo engineers for measuring information capacity or bandwidth, to evaluating the tactile channel. In this type of experiment, which originally was derived from a pilot's task of flying a given course, the subject controls a joystick that moves a spot, usually on the face of a cathode ray tube. The subject's task is to keep the spot in some reference position such as the center of the screen. However, also controlling the position of the spot is some perturbing signal (wind in the case of the pilot and airplane), which is unpredictable by the subject. The equipment compares the joystick position with the perturbing signal and uses the difference of these two signals to position the spot. Thus the position of the spot indicates the error between the joystick position and the perturbing signal.

Using wide-bandwidth noise for the perturbing signal--or, as an approximation, a sum of sinusoids--the ability of the subject to track unpredictable command signals can be measured. The performance of the subject is typically described in terms of two curves: the subject's gain as a function of frequency (that is, at a given frequency, how large a joystick movement he produces for a unit error signal on the display) and the subject's phase shift, or delay, as a function of frequency. The higher the gain and the lower the phase shift, the more nearly perfect is the subject's performance.

This type of experiment measures the over-all information-handling capability of the subject, including sensory, central nervous system, and neuromuscular factors. To try to isolate the sensory factors, we performed two experiments, identical except that in one experiment a visual display was used and in the other a tactile display was used instead. We hoped in this way to determine to what extent the tactile sense limited performance over the limitations imposed by the visual sense. The on-line computer was programmed to generate a command signal consisting of a sum of eight sinusoids. This produced a signal that appeared to move randomly and was essentially unpredictable by the subject. For the tactile display we constructed a servo system that could move a small wheel back and forth along the subject's finger, as shown in Figure 13. For the visual display the subject directly viewed the wheel as it was moved by the servo system. In both the tactile and visual experiments, the subject attempted to keep the airjet at the same anatomical reference position by moving the joystick. The response signal produced by the joystick was analyzed by the computer in real time, that is, as it was being generated.

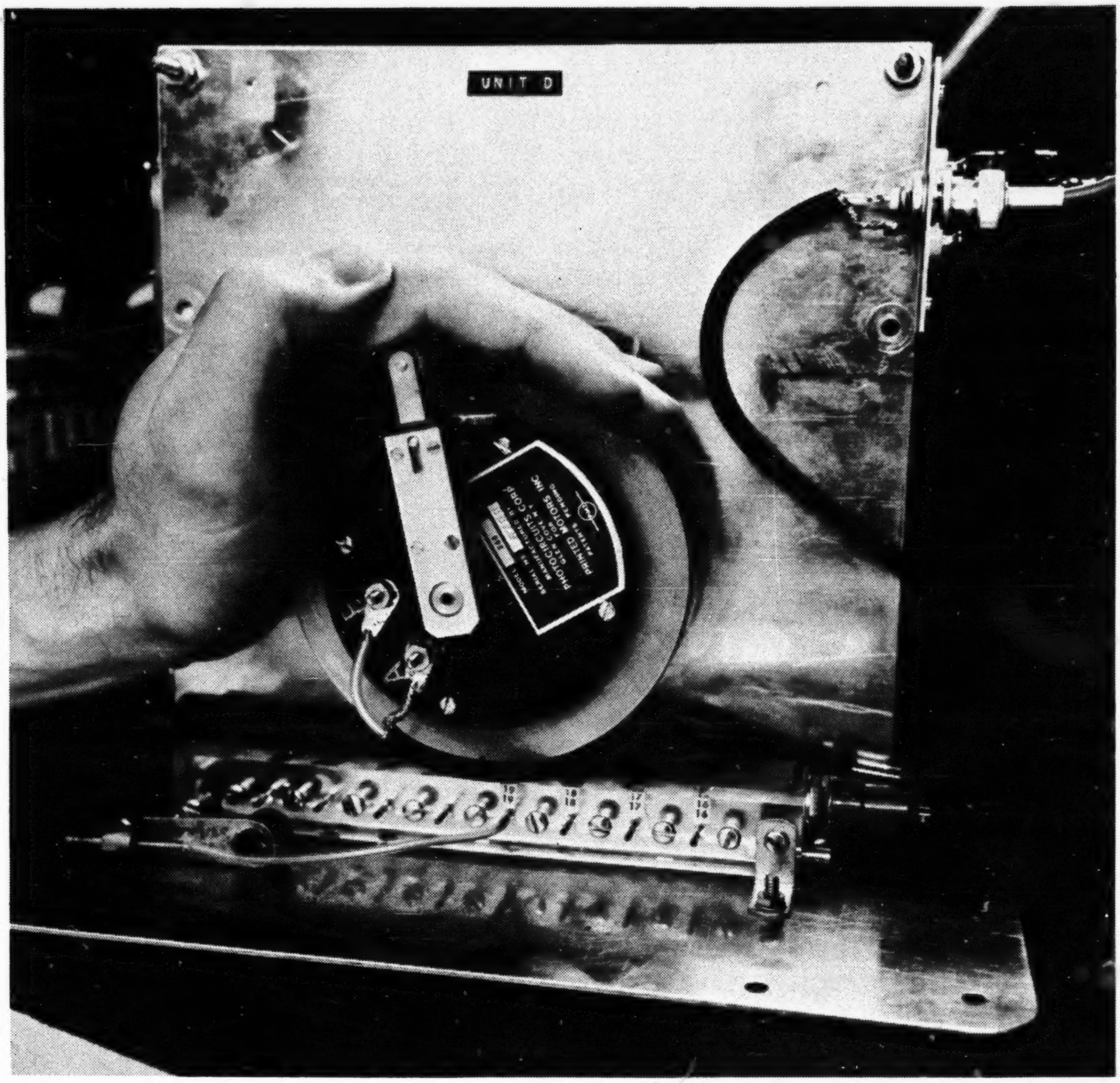
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*Figure 13. Tactile Display for Manual Control Task.* The servo motor moves the spring-loaded wheel against the finger and palm of the hand. The position of the wheel is determined by the difference between the position of a joystick, controlled by the subject's other hand, and a perturbing signal. The subject's task is to try to keep the wheel from moving from the position shown.

The results from a first experiment, averaged over four runs with each of three subjects, are shown in Figure 14. With the tactile airjet display the subjects had less gain as a function of frequency than with the visual display; however, their delay (or phase shift) was comparable even at high frequencies. This result suggests that tactile performance on this task is comparable to that attained with peripheral vision, which is also less accurate but just as rapid as that attained with foveal or central vision.

While we have only described some of our experiments here, we are made humble by the amount of research needed before complete understanding is accomplished. We are impressed by the great potential the tactile channel has for information handling, beyond simply providing a sensitive warning system to prevent us from being burned. This potential has been known, of course, for a long time--as indicated by the performance of braille readers and tactile lip readers. However, facilities for conducting basic experiments in tactual communication have generally been lacking. The ability of technology to provide us now with large arrays of small stimulators under real-time computer control should stimulate broadened interest in, and study of, the tactile channel. It is apparent that both the facility and the experiments described here can be expanded, not only to provide more comprehensive experiments in tactile perception, but also for conducting experiments involving tactile and other sensory channels simultaneously.

Our experiments have thus far been conducted with what we might call tactually naive adult subjects. One naturally wonders to what extent the tactile mode could be developed with training starting in early childhood. Are our tactually-naive subjects in somewhat the same position as those who experience vision for the first time late in life? The strong difference between our one early-blind subject and all the others at least suggests that there are great possibilities. It makes sense to consider a tactile-training program begun in parallel with the normal visual reading programs for children. Tactile-training facilities would also be useful for certain types of psychologically disturbed children, and children with other sensory deprivations. And even a relatively modest facility--in which only a few stimulators can be readily moved to various positions of the body--might well offer the neurophysiologist a more refined tool for diagnosis.

Finally, the tactile sense offers an almost unique opportunity to record peripheral as well as cortical potentials, of neural origin, in response to spatial-temporal stimuli. These potentials can be obtained from human subjects by placing surface electrodes near the ulnar or medial nerves at the wrist or elbow, near the digital nerves along the fingers, or on the scalp near the tactile region of the cortex. These signals are generally very noisy, though the desired potentials

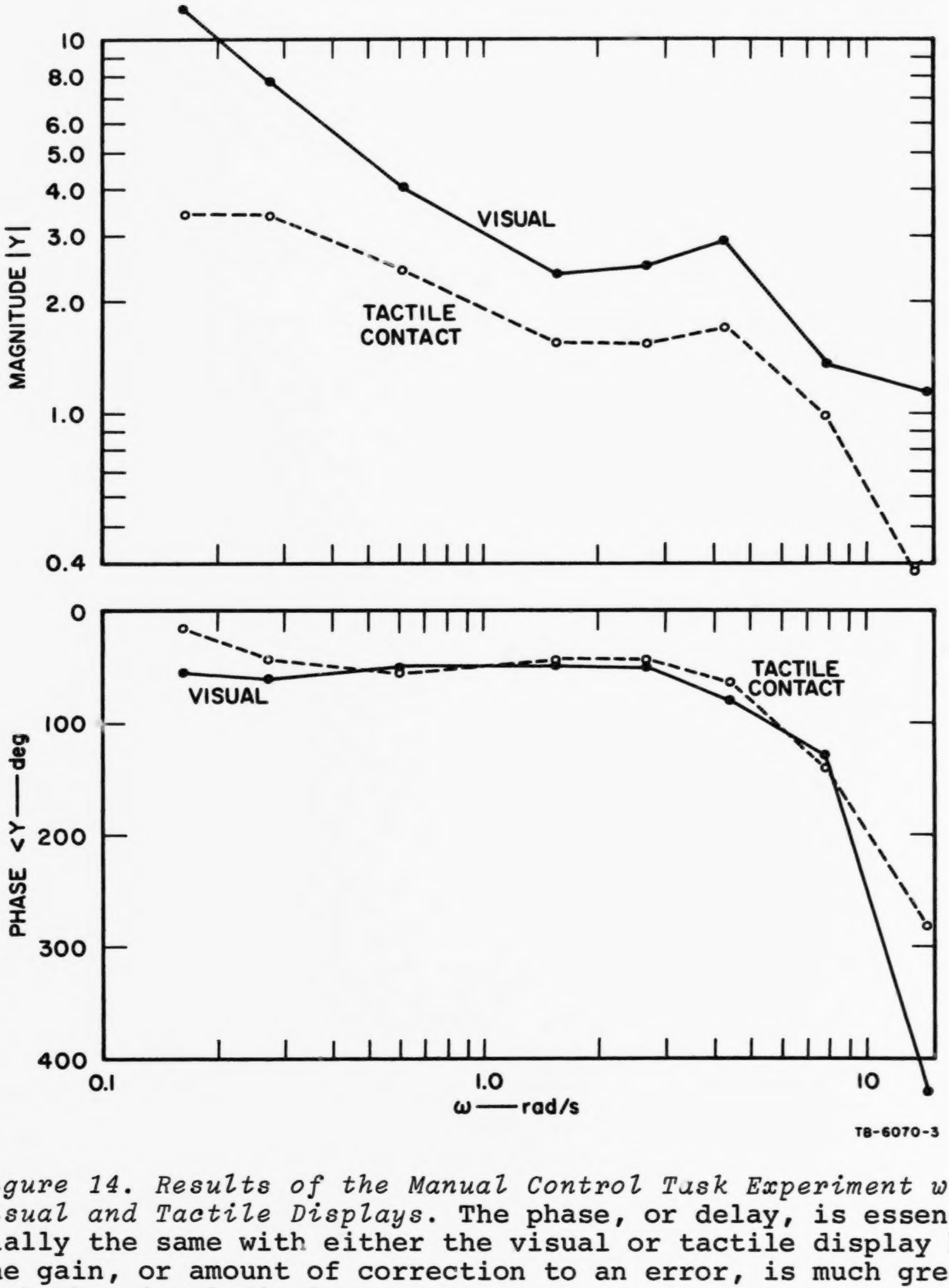

*Figure 14. Results of the Manual Control Task Experiment with Visual and Tactile Displays.* The phase, or delay, is essentially the same with either the visual or tactile display but the gain, or amount of correction to an error, is much greater with the visual display.

can be effectively abstracted by the familiar averaging technique that involves summing the measured signal over exactly the same time interval after many presentations of the same stimulus. (As these potentials are summed, the noise tends to sum or average to zero; but the portion of the potential that is time locked to the stimulus adds proportionally, so that eventually the signal appears above the noise.) We are presently pursuing this line of investigation so that we may examine these potentials under the conditions of several of the experiments described earlier in which spatial-temporal tactile patterns are presented. Hopefully, these potentials can shed new light on the processes of spatial interaction, tactile short-term memory, and temporal interaction.

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# AUTOMATED BRAILLE SYSTEM (AUTOBRAILLE)*

The automated braille system is a mode of tactile communication of text materials without the use of paper, but using the computer and other mechanical devices to form a new alternative to braille books.

## GENERAL PURPOSE

AUTOBRAILLE is intended to provide solutions for five of the problems associated with standard braille books: storage space requirements; portability (as restricted by the bulk and weight of braille books); deterioration rate of braille surfaces; high production costs; unsuitability for electronic communication.

AUTOBRAILLE allows the visually handicapped person to read from his own table-top instrument using essentially the same physical habits and techniques which he used for an ordinary braille book. The "display" is electronically actuated from control information stored on a tape recording in a nearby control unit. The controlling tape is reproduced from a master tape which has been generated by a computer working from the original natural language on punch-cards or perforated tape. Thus the AUTOBRAILLE's purpose, simply stated, is to make available a small, light-weight medium which provides for braille reading while eliminating braille production of the classical sorts.

## GENERAL DESCRIPTION

The AUTOBRAILLE system is best described in its two separate aspects: *(1)* generation of tapes for storage of braille-transducing signals and *(2)* conversion of tape signals to tactile-reading display.

1. *Generating-tonal Storage Tapes.* There are two major computer operations in the AUTOBRAILLE system. These require two unique software components and one unique peripheral hardware unit. (The two programs could be integrated or, as described here, designed to function sequentially with a computer

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storage of the primary output before treatment on the second program.) Program I transforms an alpha-numeric natural language text to codes which correspond to the 63 braille character combinations used in Grade II Braille. Program II transforms the computer's intermediate codes for the Grade II Braille symbols into a tonal code similar to that used in Bell System "Touch Tone." Thus the processed data from this second program must be output off-line through a specially-designed component which, in turn, can be recorded by an audio-range tape recording device. Another function of program II is to introduce tonal "marks" to separate the 30 characters of a standard line of the display instrument.

The major advantage of the tonal (audio-range) output is to enable the coded data to be stored, duplicated and electronically transmitted, utilizing low-cost processes for all functions. Once the master tonal tape for a document is produced, the computer is no longer required. Subsequent operations are all handled by small and inexpensive recording and display devices.

2. *Converting the Tonal Data into Tactile Display.* The visually handicapped user of the AUTOBRAILLE system manipulates three pieces of apparatus: *(1)* a 7-in. reel of 1/4-in. audio tape which holds the tonal data representing a given document, *(2)* a table-top display device (DD) about 3 x 20 x 4 in. which is the variable display of a line of 30 braille characters, and *(3)* the control unit (CU) which is the size, weight, and general appearance of a portable tape recorder.

The control unit (CU) is an automatic device which is actuated from the display device. In operation, the CU "reads" a "line" of braille code activates "lifters" in each of the cells of the characters on the DD and stops at the tonal mark which denotes a line's end. As the user hits the "next-line-please" button at the right end of the DD the CU signals "unload" to the DD, neutralizing all "lifters." The tape then "reads" the next segment of tape, loads the DD cells, and pauses at the next "line's-end" mark on the tape.

A "back-up-please" button at the left end of the ED triggers a rapid back-up-two-line's-end marks function and loads from thereafter returning to forward mode.

The display device is a reading surface with one line of 30 "6-dot" character matrices, using the standard literary braille character spacing and size. The "lifters" are covered with a strip of .5 mil mylar tape 3/4 in. wide. This strip of tape (on reels like a typewriter ribbon) protects the mechanism from finger-borne oils and dirt and provides for a sanitary refreshing of the device between users.

Actuation of the lifters is electromagnetic and the rapid-load circuits are electronic, pulse-actuated from the control unit. In this operation, the control unit delivers six binary signals to each of the cells, left to right, in turn. These trip relays in the display device remain in actuation (or nonactuation) until to "unload" signal is received.

## OPERATING CHARACTERISTICS

AUTOBRAILLE is designed to minimize the problem of converting reading habits to a new configuration. The user needs only to slide a tape cartridge into the control unit, and to operate a power switch and two control buttons located on the display device at either end of the line of braille characters. Other than these simple tasks, his reading techniques will not require modification--except that as he returns his hands for the next line he will not move down, because the next line will appear in exactly the same location as the previous line.

The tape moves rapidly when the "next-line-please" button is pressed. The unload and reload cycle is completed in less time than that required for the user to move his hands from the right end of the device back to the left end.

### Telephonic Transmission of AUTOBRAILLE Documents

One of the major advantages of the AUTOBRAILLE is its capability of low-cost electronic transmission of braille data. Using the simplest of all commercial transmission devices, the telephone line, AUTOBRAILLE tonal data can be transmitted at the probable rate of 1,000 words per minute. Using high speed transducers and wide-band equipment (cables or microwaves) transmission between libraries at much higher speeds becomes possible.

# CONSCIOUSNESS: ALTERED LEVELS IN BLIND RETARDED CHILDREN[*]

Alan A. Stone, M.D.

*A phenomenologic study of the abnormal motor activity ("blindisms") of 40 retarded blind children suggested a dichotomous classification of this behavior. These two categories of "blindisms" were descriptively designated as "alerting" and "withdrawal." A subsequent electroencephalographic pilot study of four of these children confirmed the impressions of the phenomenologic study and provided further neurophysiological information. The electroencephalographic data suggested a parallel between these categories of "blindisms" and altered levels of consciousness. The temporal relation observed in this study suggests that "blindisms" may induce physiologic changes in the level of consciousness. A further hypothesis is offered; namely, that alterations in levels of consciousness directly affect the capacity to experience objective reality, and thus "blindisms" may play an important part in the regulation of the afflicted child's relation to reality.*

In a study of sleep induction, Oswald (1) exposed human subjects, with their eyes fixed open, to a series of intense stimuli presented simultaneously and rhythmically. The stimuli were auditory and visual, and included mild electroshock that caused contraction of the leg muscles. The subjects fell asleep during this simultaneous sensory bombardment. In a parallel experiment, subjects who were exposed to these conditions were also required to keep time with their hands to the auditory stimuli (a voluntary muscular activity); sleep was also produced by this method. Sleep was defined in these experiments both by electroencephalographic and observational criteria.

[*] *This paper was first published in* Psychosomatic Medicine, [*26(1):14-19 (1964)*].

*Research for this report was done under NIMH Grant MF-17,424.*

*Mary Louise Scholl, M.D., of the Massachusetts General Hospital collaborated in the experimental pilot study by reading and interpreting the EEGs.*

Other experiments, for example, those of Gastaut and Bert (2), indicate that a stereotyped rhythmic quality is an essential characteristic of some sleep-producing stimuli.

These experimental data suggested the hypothesis that certain pathological forms of motor activity might also produce conditions similar to Oswald's sleep-induction situation. Blind retarded children habitually engage in voluntary rhythmic stereotyped movements of long duration and great intensity. It was hypothesized that these so-called "blindisms" might also create a rhythmic simultaneous sensory bombardment, and thus produce an alteration in the state of consciousness that might lead to sleep or one of the lighter stages of sleep. I attempted to test this both by observation and electroencephalographic study.

## CLINICAL OBSERVATIONS

A prolonged and highly focused study of two wards of blind retarded children was first undertaken. Forty children between the ages of 5 and 16 were observed; the majority of these children had been institutionalized for long periods. Most had been premature infants, and they suffered as sequelae both mental retardation and blindness, the latter due to retrolental fibroplasia. During most of the observation period, the children sat in a solarium without adult contact and with no toys or other equipment.

"Blindisms" proved to be universal in this group of subjects. When observed under conditions of relative social isolation, no subject was free of them. Each child's "blindisms" were individualistic and the patterns had become markedly stereotyped. Some children at age 15 spent entire days doing exactly what they did at age 2.

However, on the basis of behavioral criteria, it became clear that the clinical syndrome of "blindisms" could be divided into two general categories which were descriptively designated "withdrawal" and "alerting."

These two descriptive categories do not encompass all aspects and all forms of the behavioral complex of "blindisms." Furthermore, it seems apparent that the conditions under which the children were observed limited the response. These categories therefore represent what seem to be polarities of a variegated behavioral response. Behavior is generally difficult to categorize, but some of this difficulty is averted by restricting both the focus of observation and the setting. Clearly, in this instance, richness is sacrificed for the sake of precision.

Within these limitations, a dichotomy of "blindisms" presented itself which is based on direct observation of relatively obvious referents. The distinction between these two types of "blindism" once made is comparatively easy to demonstrate.

Withdrawal "blindisms" consist of intense rhythmic behavior which is completely involving and repetitive. A common example is intense rocking from the waist while vigorously pressing the eyes with the fist or thumbs. The intensity rises and falls in crescendo fashion, but the rate remains constant at approximately 1 per sec. in all subjects, thus the rhythm is constant. Vocalization, when it occurs, consists of rhythmic grunts, wails, or monosyllabic sounds in the same rhythm as the rocking. Hyperventilation is commonly present, and prolonged withdrawal "blindisms" are terminated on rare occasions by apneic coma-like states or by seizure activity.

These "blindisms" were designated as "withdrawal" because of *(1)* the completely preoccupying quality, *(2)* the repetitive movements at constant rate, *(3)* the concomitant loss of awareness, and *(4)* the diminished reactions to other objects and stimuli in the environment. This type of "blindism" duplicates Oswald's experiment in that it produces a rhythmic simultaneous sensory bombardment.

The sequence of percepts or stimuli, internal or external, which lead to withdrawal "blindisms" could not be clearly established within the framework of this study. However, two typical patterns were observed consistently. The first example is one that has been described in animals as well as in humans. Occasionally a child would be placed in restraints so that he would remain in bed. Such restraint seems to be the single most potent stimulus to frenzied and even violent "withdrawal blindisms." An example of the second typical pattern is as follows: A child would be sitting quietly, another child perhaps in the course of his own spinning "blindism" would trip over him. An intense affective response would then occur in one or both the children, usually an anguished cry from the child who had been previously quiet. This affective response would rapidly be blended into an unusually intense "withdrawal blindism." It seemed on empathic and intuitive grounds that these "blindisms" served as both an expressive and defensive maneuver in response to a stress.

The alerting "blindisms" are more complex and intricate. They are not of simple rhythm. They employ small muscle masses and involve behavior that often has become ritualized, for example, hand-clapping rituals which are staccato and sometimes accompanied by vocalization of words or songs. External objects were often incorporated into these rituals. When this behavior occurred, the children seemed *(1)* more aware, *(2)* more responsive to the external stimuli, and *(3)* more apt to continue to reach out for objects in the environment.

Alerting "blindisms" seem to occur in two general contexts. After a protracted withdrawal "blindism," the child may become quiet and seem to doze; suddenly he is alerted with a stereotyped hand clap and is obviously awake and active. The second context is the presentation of an apparently nonthreatening object. The following is an actual example: While feeling his way along the floor with his hands (hands are the eyes of the blind), a child comes across a misplaced stocking, grasps it, stretches athetotically, flips his hands, and begins some stereotyped sequence of grimaces and movements, which are in each case familiar to the observer who knows the child. Empathic and intuitive consideration of the emotional aspects suggest that there is surprise, pleasure, excitement, and attention at such times. Alerting "blindisms" are a regular accompaniment of feeding. Such "blindisms," because they are either not rhythmic or of complex conflicting rhythm, evidently do not produce a simultaneous sensory bombardment.

## EXPERIMENTAL PILOT STUDY

The next step of the study was to obtain prolonged EEGs of subjects who exhibited these typical "blindisms" in a particularly protracted and stereotyped manner. Four of the previously studied subjects, boys aged 9 to 11, were included in this stage. Technical problems were considerable, since to observe "blindisms" the children could not be restrained, and without restraint they tended to tear off the unfamiliar electrodes. Nonetheless, useful data were obtained on all but one of these 4 subjects. These data consisted of extended electroencephalographic tracings obtained over periods during which the electrodes remained in place and the subjects exhibited the two categories of "blindisms" described. The electroencephalograms were recorded on an 8-channel Grass instrument. Virgin solder electrodes, embedded in bentonite paste and attached to the jack box by means of long wires so as to permit random movements of the patient without disturbing the scalp contacts, were secured to the scalp by small pieces of adhesive tape. The electrodes were placed bilaterally over the central and parietal areas and over the midoccipital region. These specific areas were selected because frequency changes during drowsiness and sleep are first noted in these regions. Monopolar recordings, with reference to the ipsilateral ear, and bipolar recordings were made simultaneously on adjacent channels. The children sat on the floor in a relatively barren room similar in this respect to the solarium in which they had been originally observed.

More than 50 examples of each type of "blindism" were produced during the testing. The results to be reported were obtained repeatedly in these subjects during each testing period and on two different test days.

## Withdrawal Blindisms

The tracings revealed an association between the withdrawal "blindism" (rocking and eye pressing), and slowing of the wave pattern. In addition to generalized slowing, typical 4-6 per sec (4, 5) waves appeared which are characteristic of the drowsy state in children of this age. These specific changes occurred as quickly as 10 sec after the onset of the "blindism" (Fig. 1).

Such clear-cut changes did not occur with every transient instance of "withdrawal blindism." They did occur when the "withdrawal" was protracted and definitive. Thus, as the child shifted about, changing position, or moved restlessly, there would be momentary instances of what has been termed here "withdrawal blindisms" without immediate reflection in the EEG. However, when the child settled into an intense and sustained withdrawal "blindism," the EEG rapidly reflected a change in the level of consciousness. Further study may suggest that as in many other physiologic studies, the baseline state of the child has important implications for the total quality of the response. It should also be clearly noted that the changes which accompany withdrawal "blindisms" are similar to those which accompany normal dozing and can be obtained in any subject who simply is in the process of quietly napping. What is described here, however, is the observed, temporally related, and reproducible combination of "blindisms" and EEG changes. The specific physiologic basis by which these "blindisms" produce the alteration of consciousness has not been established. However, our technic allowed one important possibility to be ruled out, namely, a vagal effect. Since pressure on the eye is a frequent part of this "blindism," it is reasonable to consider the possibility that this induces a vagal reflex. In fact, eye pressure is a standard emergency medical procedure for certain cardiac arrhythmias because of the vagal effect. However, simultaneous EKGs revealed no bradycardia, which ordinarily precedes a change in cerebral blood flow sufficient to produce EEG findings. A reasonable hypothesis is that changes are produced either by hyperventilation or by a conditioned response originally related to hyperventilation as an unconditioned stimulus.

## Alerting Blindisms

It was noted that the subjects repeatedly terminated a spell of apparent drowsing and rate slowing with the onset of typical alerting "blindisms" (for example, staccato, less rhythmic hand-clapping rituals) and a concomitant increase in wave rate in the tracing. The alerting "blindisms" in every

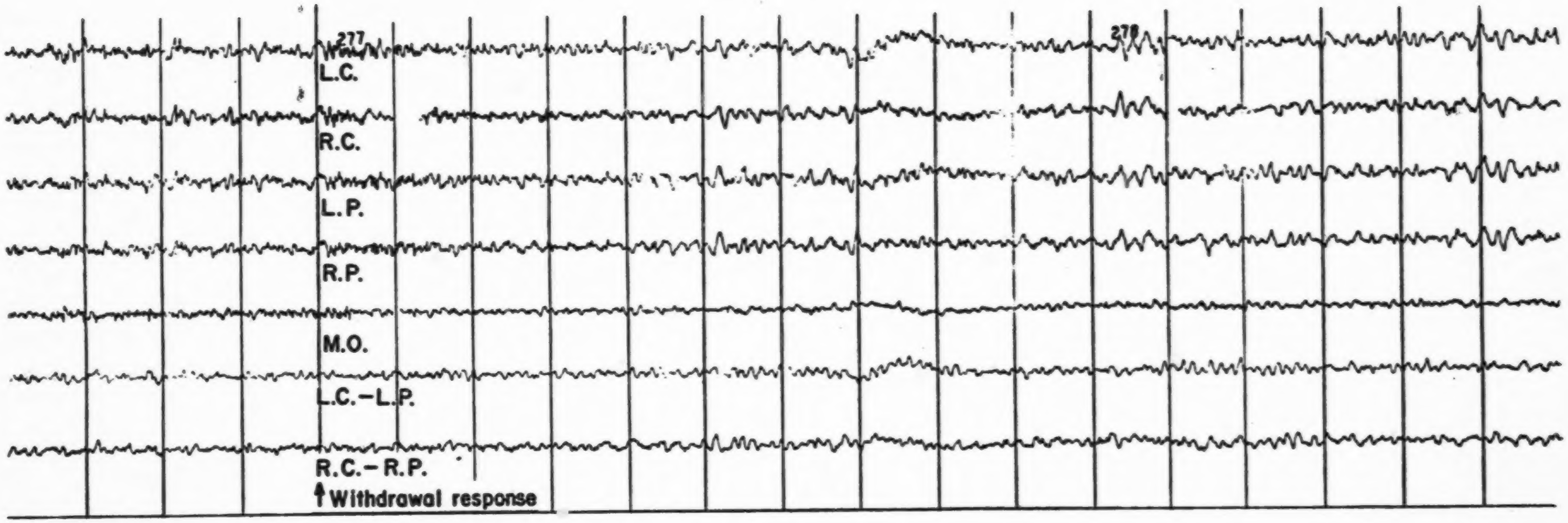

*Figure 1. Electroencephalographic Tracing.* Note control segment on the left. L.C., left central; R.C., right central; L.P., left parietal; R.P., right parietal; M.O., mid-occiput; L.C.-L.P., left central to left parietal; R.C.-R.P., right central to right parietal. Voltage is based on standard calibration; vertical lines represent time in seconds. Withdrawal "blindism" was initiated at arrow. Changes in rate and amplitude are noted within 4 sec., and 4-6 per sec. waves are apparent in leads L.C., R.C., L.P., and R.P. within 10 sec.

case resulted in an increase in rate of a previously slow EEG.

## SUMMARY

The results of this study suggest that "blindisms" found among retarded blind children are accompanied by changes in the level of consciousness as demonstrated electroencephalographically and observationally. Which is cause and which is effect cannot yet be determined; however, the temporal relations suggest that the behavioral "blindisms" induce the changes in consciousness observed. I suggest that such changes of consciousness from monent to moment must be accompanied by changes in the experience of reality, reality sense, and reality testing. If this is so, then "blindisms" must represent an important method for the child in the alteration or regulation of his contact with a stressful reality. The implications of this have considerable significance for psychological and psychoanalytic theories of ego and reality testing. The theoretical aspects of this will be presented from a psychoanalytic point of view in a subsequent paper.

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## SPEEDED HEARING—AN EXPERIMENT AND DEMONSTRATION *

A blind person listening to a reader is limited to the reader's oral reading rate. This is typically 175 words per minute, though variable from reader to reader. A person listening to a reader via a tape recorder is restricted to the same reading rate used in recording. These word rates are far lower than those normally achieved by a sighted reader reading silently. To help blind persons who must have large amounts of information available, investigators have explored many means of increasing reading rates. Foulke (1966) lists several techniques: speaking rapidly, the speed changing method, and the sampling method.

The first method, speaking rapidly, is limited to the maximum rate a person can read and cannot be varied once recorded.

The second, speed changing, is quite easy to implement. There is, however, a multiplication of each frequency component that is proportional to the change in playback speed. This frequency distortion makes the resultant voice sound like "Donald Duck."

The sampling method can be accomplished in several ways. Garvey (1953) actually cut out portions of tape and spliced the remaining sections together. This method is too cumbersome except for research purposes but specialized tape recorders, the Tempo-Regulator or Eltro Information Rate Changer are available to perform the same function. Digital techniques can be used where either sections of equal length or pauses and redundant sounds are to be removed. These techniques produce the greatest increase in information rate for a threshold level of comprehension. Garvey investigated both the sampling and speed changing methods. He found that speed increases of 200 percent reduced the intelligibility to 65 percent. Using sampling techniques, he found that the information rate could be increased by 300 percent before the intelligibility dropped to 65 percent. Klumpp and Webster (1961) have performed tests of the speed changing method with controls on the "signal to noise" ratio and had similar results.

The speed changing method is simple, for example, capstan bushings or variable speed motors. Further, it shows

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* *From MIT, Sensory Aids Evaluation and Development Center.*

promise of rate increases of 1.5 to 2.0 times normal rate. Therefore, a program was initiated at the SAEDC to explore the practical limits of this technique and to investigate corollary methods of increasing the information rate and comprehension.

Two subjects were used. One, a female, "S," is a high school senior at a private school. She has some light perception and is the only blind student in her class. The second subject, "C," is a male college senior. He has no residual vision. "S" has had very little contact with tape recorders while "C" is quite proficient in their use.

The basic equipment used was a Wollensak Model 547 tape recorder equipped with capstan bushings providing playback rates of 1.20, 1.30, 1.40, 1.60, and 1.65 times the recording rate. The American Foundation for the Blind Variable Frequency Power Supply was used to permit increases to 1.80. High quality headphones were used in all cases.

Several readers and several novels were used as listening material. Both students were thoroughly exposed to the technique before a systematic approach to a training program or learning schedule was adopted.

The students listened to one track of a reel of tape. At the end of the track, an objective test of seven or eight questions was given on the material just covered. When two tests were passed (65 percent score) in succession, the subject proceeded to the next higher speed available with the bushings. The initial rate was 1.20. Table 1 lists the number of tests required by each subject at a given speed before proceeding to the next speed.

Table 1

Number of tests necessary to pass two in succession:

| *Playback Rate* | *Subjects* | |
|---|---|---|
| | "S" | "C" |
| 1.20 | 2 | 2 |
| 1.30 | 11* | 2 |
| 1.40 | 3 | 2 |
| 1.60 | 2 | 2 |
| 1.65 | -- | 4 |
| 1.70 | -- | 2 |
| 1.75 | -- | 2 |
| 1.80 | -- | 2 |

*The subject was under great personal stress during this time.

Both subjects have apparently reached their threshold performance with rates of 1.6 to 1.8 over regular playing speed. This was achieved in month's time working approximately five hours per week. The maximum usable speed is determined by many factors, that is, voice pitch of reader, difficulty of material, quality of recording, and so forth.

Several observations can be made:

1. The students prefer a faster speed--they don't become bored as easily.
2. The students prefer a male voice at faster speeds--they are able to go faster with a male reader. The lower resonant frequency of the male permits greater frequency increases.
3. Significant savings of time can be made by a student by using this technique in studying.
4. "C" developed such confidence in the technique that he came to the Center to study for his final examination in logic. He used speeds of 1.4 to 1.6 during this time. He has borrowed the equipment to study for his next set of final examinations.

This speed changing technique should have a place in the education of blind students as it can save study time. It can be implemented to suitable tape recorders for perhaps as little as thirty dollars.

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## SWEDISH INSTITUTE FOR THE HANDICAPPED

On July 1, 1968, the Swedish government and the Swedish Central Committee for Rehabilitation (SVCR) agreed on the creation of a new institute, to be called the Swedish Institute for the Handicapped (Handikappinstitutet). The Institute will handle questions concerning technical aids for the handicapped. It is based on the activities of its predecessor, the SVCR.

The Minister of Health and Social Affairs, Mr. Sven Aspling, made the following comments, among others, in his bill to Parliament concerning the new Institute:

> *I will not deny the value of research and development work on the same project as carried out in several places, and by different research people and research institutions. Research resulting in solutions to the same problems from several sources often leads to successful results. This is especially true for basic research, which is uncommitted to topic and method. With a specialized activity directed toward the development and construction of efficient aids for the handicapped, however, the present system is not entirely satisfactory. The overall activities in the report of the Handicap Committee have been developed to care for the special needs of certain groups for aids, while activity on other aids is carried out to only a small extent.*
>
> *The Swedish Institute for the Handicapped should have an important coordinating task, therefore, in setting up a program of research and development for aids for the handicapped. The Institute can assist in distributing activity more equitably among projects devoted to various handicapping conditions. As a central coordinating agency, it can be in the position of giving priority to given projects, and to stimulating activities toward their accomplishment. The Institute can also insure that research and development findings result in projects with a practical outcome. With its analysis of the needs of the handicapped for certain kinds of aids, the Institute will be able to advise manufacturers competently about production and marketing problems.*
>
> *I feel that this task of the Institute is of the greatest importance, since the production of special aids for the handicapped is often made only in limited runs.*

The Minister stressed the fact that the Institute will continue to test aids, and that the results of tests will be the basis upon which the Social Welfare Board forms its opinions about the feasibility of subsidy for their development. He also stressed the importance of information dissemination:

*It is also important that information be sent to all those engaged in, or who depend on, these activities. Information should therefore comprise details about planned and completed projects, and about the status of those ongoing; and details should indicate results obtained and methods used. The Institute is thus also a documentation and information center for questions about research and development of special aids. At the start of the research and development program it will establish, the Institute will also distribute information about needed aids, including details on the result of testing and evaluation of them.*

Finally, the Minister stressed the importance of training of personnel in the field of technical aids.

The new Institute takes over the responsibilities of the SVCR for the International Society for the Rehabilitation of the Disabled's Committee on Technical Aids, Housing, and Transportation (ISRD/ICTA).

The board of the Institute is composed of representatives from both government and from the SVCR. The Chairman is Mr. L. Hultström, Deputy Director General of the National Social Insurance Board. The Director of the Institute is Mr. Karl Montan, who is also Chairman of the ICTA.

The total budget of the Institute will amount to about 4.5 million Skr (about U.S. $900,000) for the fiscal year 1968/69.

Stockholm, September 1968.

# COMPUTER DISPLAYS AS OCCUPATIONAL AIDS FOR THE BLIND: PRELIMINARY REPORT ON RESEARCH IN PROGRESS

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Research is being undertaken to determine the extent to which existing computing facilities can prepare tactographic information displays for the blind which are comparable in scope and function to visual displays used by sighted persons. Making embossed drawings, diagrams, flowcharts, graphs, and similar nontextual braille material is typically a slow and costly process, requiring specialized equipment and skilled manpower. It can be demonstrated that certain specific needs of the blind for embossed information displays can be met without special equipment or skilled assistance, by a conventional digital computer, using standard, unmodified impact printers. Such displays can be obtained quickly enough, and cheaply enough, to be of practical value in everyday applications as routine occupational aids for many blind professionals or skilled workers, who need not have any expertise in computer science to use them.

When the range of occupational choices available to a person with a handicapping physical disability is examined, the skilled occupations and the professions seem to offer fewer obstacles and greater promise of feasibility than do the unskilled and semi-skilled occupations. The deemphasis on factors of physique, such as physical stamina, perceptual or motor skill, and a pleasing appearance, and the greater emphasis on intellectual and social factors, contribute to this feasibility. Persons with a severe visual impairment, or who are blind, and who seek and obtain the requisite training for entry into a skilled occupation or profession, often discover a paradox which is rarely anticipated, and often not very well understood.

The paradox is that becoming a teacher, an engineer, a lawyer, a computer programmer, or a social worker, brings the blind person not only the desired opportunity for occupational achievement, but also brings him an increased need for, and dependence upon, printed information. Such things as textbooks, reference manuals, lab reports, schematic diagrams, flowcharts, histograms, and similar information displays are indispensable to the professional person. They are no less important to the blind professional, who often spends a large part of his waking life acquiring and/or assimilating such material. He uses public and private resources to varying degrees, and employs braille or audio recordings, also to varying degrees. He often appears to exist in a chronic state of information hunger in order not to become antiquated in his own field of specialization, or professionally obsolete.

A comprehensive rehabilitation program for the blind, therefore, should assign a high priority to efforts at identifying, evaluating, and disseminating techniques which would alleviate the informational deficiencies of the blind, since these have a direct bearing on the maintenance and enhancement of his professional competence.

During the past six years, some 200 blind persons have been trained and have obtained employment as computer programmers. This occupation became feasible largely due to the exploitation of three informational innovations. The first is a device resembling a braille slate with which a blind person can locate and identify the holes in a punched card. The second is a battery powered photosensitive probe, with which a blind person can examine the lights which display the contents of the various registers and indicators on the console panel of a small computer. The third is the insertion of a length of elastic or rubber tape in the computer's printer, between the paper and the mechanism which strikes it. When periods are printed under heavy pressure with the paper thus cushioned, raised dots are produced. With the proper program, these raised dots can be formed so as to be readable as ordinary braille characters. The blind computer programmer, therefore, has the same access as does the sighted programmer to program listings, compiler diagnostics, and system messages; and in some cases to entire copies of the reference manuals themselves on which the daily work of the programmer depends directly.

While it is important that a new occupation has become feasible for qualified blind persons, it is more important in the long run that increasing numbers of the blind are acquiring skills in data processing and information science. There are enormous benefits to be derived from the imaginative application of those technologies to the problems of the blind. As the "computer-competent blind" community grows in numbers, more and more such applications will be made, at first to meet the informational needs within that group of specialists, but ultimately for the benefit of larger groups of the blind.

In programming digital computers to produce "computer braille" on high-speed impact printers, a typical device may print as many as 132 characters per line. With line spacing of 8 lines per inch, 80 such lines fit comfortably on a 15- by 11-in. page. If every third position on a line, and every fourth entire line, are left blank, the page is effectively divided into a matrix of 44 by 20 braille cells, consisting of two print positions on each of three lines. Since the raised dots appear on the side of the paper opposite to that on which the periods are printed, the program which translates the flow of input information into the output stream of periods and blanks must print that stream from right to left, so that the braille may be read from the reverse side of the paper in its normal direction, from left to right.

In programming to produce nontextual displays in tactographic form, the central difference is that the page is not considered to be a matrix of 44 by 20 cells, but rather a matrix of 132 by 80 print positions which may contain any of a large number of characters or may be left blank. For the most part the different characters are not distinguishable by touch. However, when one region of the page is filled with one character, and another region is filled with a different character, there are a few easily distinguishable textures that can be produced. A region speckled with periods can be distinguished from one that is horizontally striped with hyphens, even though the isolated period and the isolated hyphen may not be differentiated. Similarly, each of the above textures may be distinguished from a vertically striped region produced by printing the numeric character "1" or the logical "or" symbol.

There is an unproven mathematical law which states that no more than four different shades are required to color the various regions of an ordinary map in such a way that no two regions with a common boundary are made the same hue. While this law has not been proven, neither has it been possible for anyone to devise a map so complex that more than four colors are required. Since textures are analogous to colors in the preparation of tactographic information displays, and since there may be only four readily distinguishable textures that can be produced by the methods described above, the importance of the four color (or four texture) map problem for this area of work is evident.

Preliminary work by the author at Washington University has resulted in a program which enables the campus computer to produce tactographic displays on its standard high speed printer, consisting of figures whose various closed regions are given one of four textures according to the four color map principle. The program requires for its input a series of numeric values which are interpreted as the spatial coordinates of a series of points, which in turn are the corners of the figure being defined. The input to the program also consists of a series of key words, which instruct the program how to scale, position, label, and otherwise manipulate each figure before it is displayed. Figures may be superimposed, drawn in outline or textured form, or with some figures outlined and others textured within the same display. Test displays have included simple geometric shapes, separated or overlapped, a two-and-one-half turn spiral band or path, and histograms or bar graphs of various sizes. The output is limited in complexity only by the ingenuity required to specify the necessary numeric input values.

Having established that a wide variety of shapes, figures, contours, and paths can be generated and automatically displayed in embossed form, it now remains to bridge the gap which exists between the information which it is desirable to display, and the string of numbers and key words required as input to the tactographic display program. Future steps in the current line of research will be aimed at the development of relatively simple programs which will accept a series of user oriented statements from a terminal keyboard or from punched cards, and generate from those statements the necessary information to produce tactographic displays. Thus, the blind engineer could produce schematic diagrams from their verbal descriptions, flowcharts from their underlying logical statements, etc. The blind psychologist could obtain psychological test profiles from a set of subtest scores and a few identifying key words. With such routines available, the blind specialist whose professional or occupational affiliation provides him with access to small amounts of computer time can use existing local facilities to obtain tactographic displays which will increase his effectiveness within his own specialty, and which simply are not available in any other form.